DOCUMENT RESUME

ED 265 356	CE 043 312

TITLE	Machinist (AFSC 42750).
INSTITUTION	Air Univ., Gunter AFS, Ala. Extension Course Inst.
PUB DATE	14 Jun 83
NOTE	584p.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF03/PC24 Plus Postage.
DESCRIPTORS	Behavioral Objectives; Correspondence Study; Equipment Utilization; Learning Activities; *Machine Tools; *Machinists; *Metallurgy; *Metal Working; Military Personnel; Military Training; Postsecondary Education; Shop Curriculum; *Trade and Industrial Education
IDENTIFIERS	Air Force

ABSTRACT

This four-volume student text is designed for use by Air Force personnel enrolled in a self-study extension course for machinists. Covered in the individual volumes are machine shop fundamentals, metallurgy and advanced machine work, advanced machine work, and tool design and shop management. Each volume in the set contains a series of lessons, exercises at the end of each lesson, a bibliography, and answers to the exercises. Supplementary volume review exercises are also provided. A fifth volume, a change supplement, is also provided. (MN)

****
*   Reproductions supplied by EDRS are the best that can be made   *
*   from the original document.   *
****

ED265356

MACHINIST

(AFSC 42750)

Extension Course Institute
Air Training Command

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

CE043312

ECI COURSE MATERIALS SHIPPING LIST

COURSE NUMBER	COURSE TITLE	EFFECTIVE DATE
53150	MACHINIST (AFSC 42750)	14 Jun 83

INSTRUCTIONS The following materials are needed to complete this course. *Check this list immediately upon receiving your course package, and if any materials are missing or incorrect (numbers don't match) notify ECI immediately.* Use the ECI Form 17 for this purpose, and be sure to include your identification number, address, course and volume number, and VRE form designation (if a VRE is involved). Send all correspondence separately from your answer sheet.[1]

ITEM	TYPE	DESIGNATION OR TITLE	INVENTORY CONTROL NUMBER	VRE ANSWER SHEET IDENTIFICATION
1	ENV	ECI RETURN ENVELOPES (4 EACH)		
2		YOUR KEY TO A SUCCESSFUL COURSE	M-140	
3	VOL	VOL 1, Machine Shop Fundamentals	53150 01 7702	
4	VRE	VOLUME REVIEW EXERCISE (VOL 1)	53150 01 25	53150 01 25
5	VOL	VOL 2, Metallurgy and Advanced Machine Work	53150 02 7702	
6	VRE	VOLUME REVIEW EXERCISE (VOL 2)	53150 02 25	53150 02 25
7	VOL	VOL 3, Advanced Machine Work	53150 03 7701	
8	VRE	VOLUME REVIEW EXERCISE (VOL 3)	53150 03 24	53150 03 24
9	VOL	VOL 4, Tool Design and Shop Management	53150 04 7704	
10	VRE	VOLUME REVIEW EXERCISE (VOL 4)	53150 04 21	53150 04 21
11	SUPP	CHANGE SUPPLEMENT (VOLs 1, 2, 3, and 4)	53150 00 S01 8205	

SPECIAL NOTE: DISREGARD THE AFSC PRINTED ON THE COVER OF THE TEXTS. THIS CDC IS FOR AIRMEN ON UPGRADE TRAINING TO AFSC 42750 ONLY.

NOTE: YOU ARE NOT REQUIRED TO POST ANY CHANGES LISTED ON THIS SHIPPING LIST WHICH CORRECT TYPOGRAPHICAL ERRORS, UNLESS SUCH ERRORS CHANGE OR OTHERWISE AFFECT THE MEANING OF THE MATERIAL.

NOTE: DIRECT ANY QUESTIONS OR COMMENTS RELATING TO ACCURACY OR CURRENCY OF TEXTUAL MATERIALS TO AUTOVON 862-2385.

---

[1] *SEE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS.*

ECI FORM JUL 81 25 PREVIOUS EDITION IS OBSOLETE.

PAGE 1 OF 3 PAGES

LIST OF CHANGES

COURSE NO.
53150

EFFECTIVE DATE OF SHIPPING LIST
14 Jun 83

CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.

1. CHANGES FOR THE TEXT: VOLUME 3

a. Page 15, col 1, line 16: Change "1.115" to "1.155."

b. Page 62, Exercises (431)-4: Change "a hardened" to "an annealed."

2. CHANGES FOR THE VOLUME REVIEW EXERCISE: VOLUME 1

a. Page 2, question 1: In the stem of the question, change "531X0" to "427X0" and change "531" to "42." Choice a: Change "metalworking" to "aircraft systems maintenance." Choice b: Change "machinist" to "fabrication." Question 2: In the stem of the question, change "531X0" to "427X0." Choice c: Change "metalworking career field" to "fabrication career field subdivision."

b. Page 2, question 3: In the stem of the question, change "531X0" to "427X0." Choice b: Change "metalworking" to "fabrication." Choice d: Change "metalworking" career field" to "fabrication career field subdivision." Question 4, choice b: Change "metalworking" to "fabrication."

c. Page 3, question 11: In the stem of the question, change "metalworking" to "fabrication." Choices a, c and d: Change "metalworking" to "fabrication." Question 12, choice b: Change "metalworking" to "fabrication." Question 13: In the stem of the question, change "metalworking" to "fabrication."

d. Page 11, question 78, choice a: Change "7.4604" to "7.4606."

e. Page 14, question 98: In the stem of the question, delete "strain."

f. Page 15, question 108: In the stem of the question, change "contains several damaged screws is to" to "containing several damaged screws must be removed is to." Choice a: Change "screw" to "screw head." Question 109, choice c: Change "the use" to "using."

g. The following questions are no longer scored and need not be answered: 6, 7, 25, 35, 42, 44, 85, and 118.

3. CHANGES FOR THE VOLUME REVIEW EXERCISE: VOLUME 3

a. Page 3, question 14, choice c: Delete the duplicate "the arc plus."

b. Page 4, question 24, choice a: Between "than" and "14°" insert "the."

c. Page 5, question 27, choice a: Change "from left to right" to "toward the operator's side of the machine."

d. Page 6, question 32, choice b: Change "with" to "until."

LIST OF CHANGES

COURSE NO. 53150	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 14 Jun 83	

3. CHANGES FOR THE VOLUME REVIEW EXERCISE: VOLUME 3 (Continued)

e. Page 9, question 57, line 2: Change "assembly" to "the nature of the material."

4. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 4

The following questions are no longer scored and need not be answered: 3, 15, 17, 24 and 31.

NOTE: Change the currency date on all volumes to "November 1982."

(Page 3 of 3) of ECI Form 25

53150 00 S01 8205

CHANGE SUPPLEMENT

CDC 53150

MACHINIST

(AFSC 42750)

Important: Make the corrections indicated in this supplement before beginning study of Volumes 1, 2, 3, and 4. This supplement contains both "pen-and-ink" changes and replacement pages. It is perforated and three-hole-punched so that you can tear out the replacement pages and insert them in your volumes. You are not required to post any changes listed in this supplement which correct typographical errors, unless such errors change or otherwise affect the meaning of the material.

Extension Course Institute

Air Training Command

CHANGES FOR THE TEXT: VOLUME 1

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
Front cover		4	Change “(AFSC 53150)” to “(AFSC 42750).”
9R	007-4	1, 2	Change “As what type of mail” to “How” and delete “may” in line 2.
9R		11 fr bot	Change “etc.,” to “etc.),.”
12R		1	Change “grope” to “group.”
12R		23, 24	Change to read “By turning to the reference in the GSA catalog,....”
20L		12 fr bot	Insert *“Ground”* before *“Accident.”*
22R		9 fr bot	After “fires.” add the following sentence: Every shop should also have a supply of dry sand or, if available, a dry powder extinguisher for use on titanium and magnesium fires.”
22R		23 fr bot	Change “a” to “at.”
26R		1-6 fr bot	Delete entire paragraph beginning with “You must be...”
27L		1, 2	Delete the first two lines.
28L		8	Change “is” to “in.”
28L		11	Change “o” to “to.”
28R		16 fr bot	Change “if” to “in.”
29L		16 fr bot	Change “inly” to “only.”
29R		1	Add “(“between “unit” and “i.e.”
34	Fig. 4-7		Add the following callout legends at the bottom of figures 4-7: A. Sectioning lines B. Extension line/leader line C. Dimension line D. Centerline E. Phantom line F. Outline G. Hidden line H. Cutting plane line I. Break line J. Border line
38L		3	Change “areas” to “are as.”
40R		3	Change “2.247” to “3.247.”
40R		16	Change “allownace” to “allowance.”
41R	024-3, 4		Add “what type of” between “of” and “tolerance” in both questions. Change period to question mark in end of both questions.
41R		13 fr bot	Add comma after “of the metric system.”
42L		21	Change “0.3937” to “0.03937.”
42R		12 fr bot	Change “0/52” to “9.52.”
43L		13 fr bot	Change “acutally” to “actually.”
43L		5 fr bot	Change “value in” to “the value of.”

Page-Col.	*Subject*	*Lines*	*Correction*
44L		14	Change “on” to “one.”
46R		5 fr bot	Change to read “When you find one that is loose, fix . . . .”
46R		5 fr bot	Change “objecet” to “object.”
48R		5	Change “slop” to “slot.”
49L		15 fr bot	Change “posiion” to “position.”
56L		25 fr bot	Change “iside” to “inside.”
56R		15	Change “or” to “of.”
58L		12	Change “or” to “of.”
59L	Fig. 5-13		Add the following beneath the bottom micrometer picture: “Correct Reading 0.224 inch.”
60L		18	Insert “readings” at beginning of line.
63R	035-3	2	Change “iside” to “inside.”
63R		18	Add “caliper” between “vernier” and “can.”
64	Fig. 5-17	Legend	Change “Varnier” to “Vernier.”
64L		5 fr bot	Change “28” to “18.”
70R		3 fr bot	Change “a” to “an outside.”
70R		1, 2 fr bot	Delete “You measure. . . the buttons, and.”
73L		17	Change “itens” to “items.”
73L		18 fr bot	Change “kayseats” to “keyseats.”
73R		4 fr bot	Add at the end of line: “. . . tolerance.”
80L		20 fr bot	Change “then” to “they.”
80R		14	Change “0.262” to “0.062.”
83L		5 fr bot	Change “the” to “then.”
84R		10	Change “lockpit” to “lockpin.”
86L		18 fr bot	Change to read “. . . stud or the bottom few threads on . . .”
86R	Fig. 6-13		In the top left view, change the dotted lines inside the four small circles to solid lines.
86R		12	Change “spark in” to “spark plug in.”
87R		17 fr bot	Change “1/4” to “3/4.”
89L		10 fr bot	Change “form” to “from.”
94L		15	Change “Helti-Coil” to “Heli-Coil.”
98		13	Change “AFM” to “AFR” and “*Manual*” to “*Regulation.*”
98		15	Change “AFM” to “AFR” and “*Manual*” to “*Guide.*”
98		16	Insert “*Ground*” before “*Accident.*”
101L	023-1	2	Change “does” to “does not.”
103L	045-1	1-3	Change answer to read “It is smaller, cheaper, more easily replaced, and more effective on studs only slightly above the surface of the part.”
104R	056-4	1, 2	Change answer to read “By tapping lightly on it with a hammer.”

Page Changes:

Remove Pages	*Insert Pages*
iii-iv	*iii-iv*
1-6	1-6
23-24	23-24
71-72	71-72
95-96	95-96

Preface

THIS CAREER Development Course will help you qualify in the upgrade knowledge requirements for the machinist specialty. As the self-study portion of your on-the-job training program, it deals with job-related knowledge requirements for machinists. CDC 53150, consisting of four volumes, contains the upgrade knowledge that you need in order to progress from 3 to 5 skill level of your career field ladder. Basically, Volume 1 contains information about your career field, security, safety, shop drawing, hand and special tools, and hardware removal and replacement. Volume 2 provides information on the properties and characteristics of various metals, as well as information on lathe press, drill press, and contour machine work. Volume 3 covers milling machines, shapers, grinding machines, and the inspection of machine parts. Volume 4 discusses tool design and fabrication, technical publications, and supervision and management system.

In addition to satisfactorily completing this course and the course examination, you must satisfy on-the-job proficiency requirements of your unit OJT program before you advance in skill level. Therefore, you should not expect this course to be an "Aladdin's genie" that will grant your every wish. Instead, you should expect it merely to contain the knowledge required for advancement in your career field. You must study to acquire this knowledge. However, you may have already acquired much of this information from your experience as an apprentice machinist.

Now note the chapter titles on the contents page for Volume 1. Chapter 1 covers career ladder progression and the duties and responsibilities of the various skill levels within the machinist specialty; Chapter 2, the security classification system, communication security, the Air Force Supply System, and property accountability; Chapter 3, safety, plus ground mishap reporting; Chapter 4, shop drawings; Chapter 5, hand tools, special tools, and layout work; and Chapter 6, removal and replacement techniques for studs, plugs, screws, and inserts.

Each chapter has numbered sections that are broken down into objectives on individual knowledge items. Read each objective; then complete it by reading the text and doing the review exercises at the end of each text segment. Check your answers with those given at the end of the volume. The exercises should help you to determine whether you have attained each objective and will reinforce your learning of the information that you need. When you complete the volume, use the volume review exercise in a similar manner. Both types of exercises can help you greatly if you use them as testing devices to tell you what your areas of weakness are and as teaching devices to emphasize for you the important points that you should remember.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: Tech Tng Cen/TTGXW, ATTN: SMSgt John D. Wurm, Chanute AFB IL 61868. If you need an immediate response, call the author, AUTOVON 862-2385, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

If you have any questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercises, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this person can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferrably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of July 1981.

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objectives gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Machinist Career Field

HAVE YOU EVER stopped to think of how your job as a machinist is related to the rest of the Aircraft Systems Maintenance Career Field? Considering the fast pace involved with attaining your present position, you probably haven't. As you study this chapter, you will learn how the machinist specialty is organized in relation to the Aircraft Systems Maintenance Career Field. Also, you will become better acquainted with the numerous duties that you will be confronted with as you progress up the machinist career field ladder.

Every craftsman needs some background information about his specialty. The purpose of this chapter is to provide a portion of that background knowledge. It deals with career ladder progression and the duties and responsibilities of the various skill levels within the machinist specialty.

1-1. Machinist Career Ladder

A very important factor in advancement in the Air Force is an understanding of the career field progression process. In this section, we shall discuss what your Air Force specialty code means and the advancement process by skill levels to the position of fabrication superintendent.

001. Interpret Air Force Specialty Code 427X0.

A career field is made up of a group of positions, Air Force Specialties (AFSs), requiring common qualifications. An AFS is identified by title and code. The code is made up of five digits called Air Force specialty code (AFSC). The AFSC identifies the major career field, the career field subdivision, the proficiency level, and the specific career ladder or specialty.

Now, let's examine your present AFSC, which is 42730. In an AFSC, the first two digits identify the major career field; the third digit identifies the career field subdivision; the fourth digit identifies the proficiency or skill level; and the fifth digit in conjunction with the other digits, identifies the specific specialty or career ladder. Therefore, "42" identifies your major career field, which is the Aircraft Systems Maintenance Career Field. This career field is divided into three subdivisions: Aircraft Accessory Systems, Aircraft Propulsion, and Fabrication. The "7" in "427" designates the fabrication subdivision of which you are a part.

The next (4th) digit identifies the skill level. Since this is a "3," you would be classified as semiskilled (3 skill level). As you progress up the machinist career ladder, the fourth digit changes to reflect your increased proficiency (42750—skilled, 42770—advanced skilled). An "X" may also be used in the fourth position (427X0); however, it does not reflect a particular proficiency level but is used when referring to *all* skill levels within an AFS.

The "0," in conjunction with the other digits in AFSC 42730, identifies the machinist career ladder (specific specialty) within the fabrication subdivision. There are five other specialties within the subdivision, as shown in figure 1-1. A graphic display of the AFSC that you are training for (42750) is as follows:

42	Career Field	Aircraft Systems Maintenance
7	Subdivision	Fabrication
5	Skill Level	Skilled
0	Specific AFS	Machinist
42750	Complete AFSC of the Machinist	

Exercises (001):

1. In AFSC 42750, what does the "42" indicate?

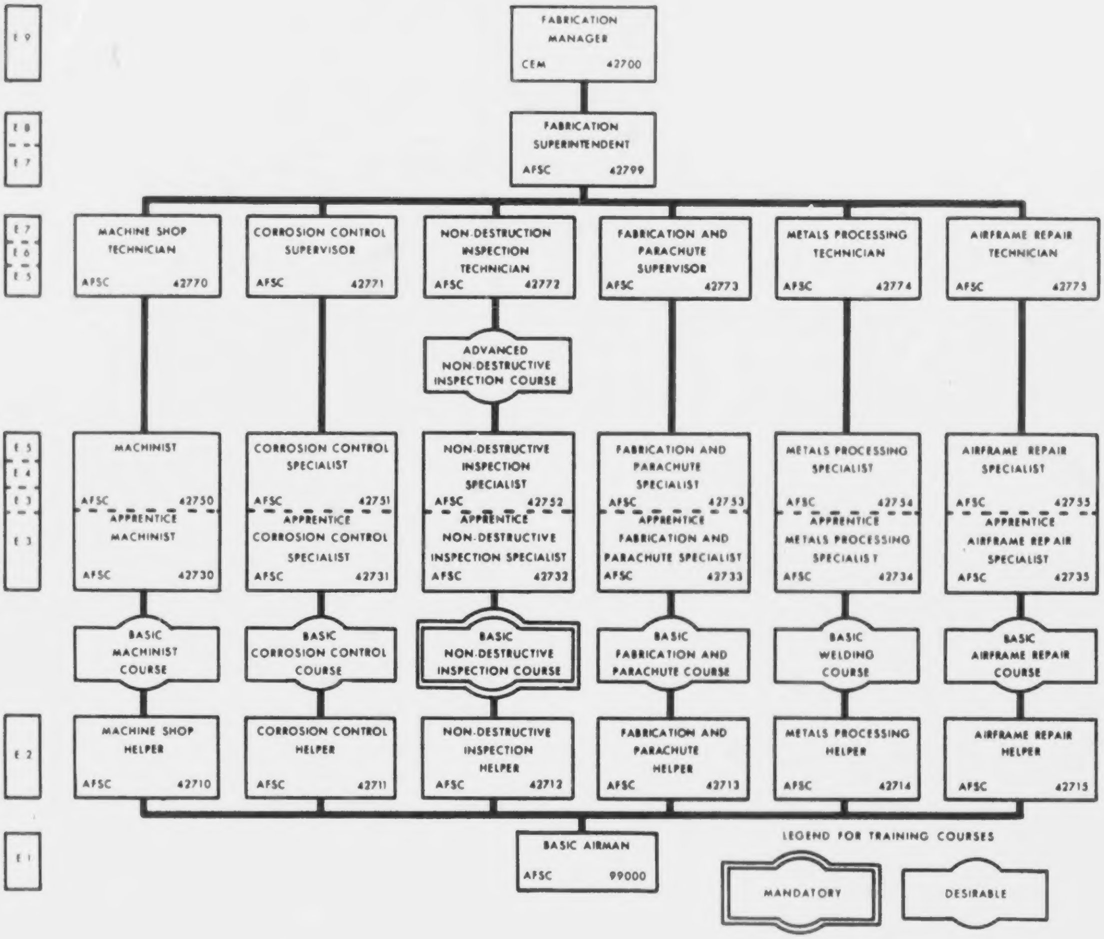

E 9
FABRICATION MANAGER
CEM 42700
E 8
E 7
FABRICATION SUPERINTENDENT
AFSC 42799
E 7
E 6
E 5
MACHINE SHOP TECHNICIAN
AFSC 42770
CORROSION CONTROL SUPERVISOR
AFSC 42771
NON-DESTRUCTION INSPECTION TECHNICIAN
AFSC 42772
FABRICATION AND PARACHUTE SUPERVISOR
AFSC 42773
METALS PROCESSING TECHNICIAN
AFSC 42774
AIRFRAME REPAIR TECHNICIAN
AFSC 42775
ADVANCED NON-DESTRUCTIVE INSPECTION COURSE
E 5
E 4
E 3
E 3
MACHINIST
AFSC 42750
APPRENTICE MACHINIST
AFSC 42730
CORROSION CONTROL SPECIALIST
AFSC 42751
APPRENTICE CORROSION CONTROL SPECIALIST
AFSC 42731
NON-DESTRUCTIVE INSPECTION SPECIALIST
AFSC 42752
APPRENTICE NON-DESTRUCTIVE INSPECTION SPECIALIST
AFSC 42732
FABRICATION AND PARACHUTE SPECIALIST
AFSC 42753
APPRENTICE FABRICATION AND PARACHUTE SPECIALIST
AFSC 42733
METALS PROCESSING SPECIALIST
AFSC 42754
APPRENTICE METALS PROCESSING SPECIALIST
AFSC 42734
AIRFRAME REPAIR SPECIALIST
AFSC 42755
APPRENTICE AIRFRAME REPAIR SPECIALIST
AFSC 42735
BASIC MACHINIST COURSE
BASIC CORROSION CONTROL COURSE
BASIC NON-DESTRUCTIVE INSPECTION COURSE
BASIC FABRICATION AND PARACHUTE COURSE
BASIC WELDING COURSE
BASIC AIRFRAME REPAIR COURSE
E 2
MACHINE SHOP HELPER
AFSC 42710
CORROSION CONTROL HELPER
AFSC 42711
NON-DESTRUCTIVE INSPECTION HELPER
AFSC 42712
FABRICATION AND PARACHUTE HELPER
AFSC 42713
METALS PROCESSING HELPER
AFSC 42714
AIRFRAME REPAIR HELPER
AFSC 42715
E 1
BASIC AIRMAN
AFSC 99000
LEGEND FOR TRAINING COURSES
MANDATORY
DESIRABLE

Figure 1-1. Fabrication career field subdivision.

2. Why is an "X" sometimes used in the fourth-digit position of an AFSC?

3. How does the last digit function in AFSC 42730?

002. Indicate the primary qualifications and factors involved or required in progressing from a machine shop helper to a fabrication superintendent through the machinist career ladder.

There are three basic skill levels in the machinist specialty—3, 5, and 7 skill level.

A fourth skill level (42799 at the 9 skill level) is attainable by the machinist, through it is not specifically a part of the specialty. This 9 skill level (fabrication superintendent) is the top rung of all the specialties within the fabrication career field subdivision, as shown in the Fabrication career field subdivision chart (fig. 1-1). Progressing to this 9-level position looks simple enough on paper, but let's examine what is really involved in the advancement process.

When airmen are assigned to the fabrication career field subdivision during basic training, they are given the AFSC 42710. This code identifies them as being unskilled, but places them at the bottom rung of the machinist career ladder. Airmen progress from this unskilled position to the 3 skill level in one of three ways. Some are sent to the formal technical training school at Aberdeen Proving Grounds in Maryland. Others are sent directly to the field and entered into an on-the-job training (OJT) program similar to the one in which you are presently involved. Also, a few airmen, because of previous machinist experience, are given the opportunity to take a by-pass specialist test. Upon passing the test, they are awarded a 3 skill level and sent directly to a duty assignment.

Progression from the 3 skill level or apprentice machinist to the 5 skill level (skilled machinist) is accomplished only through OJT. This, as you probably know by now, consists of both knowledge training and proficiency training. (A detailed discussion of OJT and how to conduct it will be included later in this course.) Minimum time requirements for OJT at various levels are contained in *AFR 50-23, On-The-Job Training*.

Before the 7 skill level (machine shop technician) is awarded, an airman must first be promoted to the rank of staff sergeant (E-5). Then he again enters an OJT program for a specified time. When he has successfully completed the requirements of this OJT program, he can be upgraded.

An airman must be a master sergeant to be awarded a 9 skill level (fabrication superintendent). Also, he must pass the USAF Supervisory Examination.

As you can see, there is a lot of work and study involved in reaching the 9 skill level. Therefore, *now* is the time to develop good study habits. They will prove invaluable to you as you progress up the career ladder.

Exercises (002):

1. List three ways that an airman might progress from AFSC 42710 (machine shop helper) to AFSC 42730 (apprentice machinist).

2. What AFSC in the machine shop career ladder is reached only through OJT and has no requirement for any specific rank?

3. A "rank" factor is involved in advancing to two of the skill levels in the advancement process. List the two levels and the required rank for each.

4. What can you, as a 5-level trainee, do *now* to enhance your chances of progression up the machinist career field ladder?

1-2. Duties and Responsibilities

In the previous section, we discussed the progression up the machinist career ladder and you learned that there are several positions that you will fill as you advance up that ladder. There is, however, more to that progression than simple advancement. Each step up the ladder will present you with new and more difficult problems, as well as increased responsibility. In accomplishing the following two objectives, you will learn some of the duties and responsibilities of the apprentice machinist, machinist, machine shop technician, and fabrication superintendent.

003. Analyze the difference in responsibilities between an apprentice machinist (3 level) and a machinist (5 level).

Apprentice Machinist. As we have stated earlier, a 3 skill level means semiskilled or apprentice. As an apprentice machinist, you are expected to know the general principles of metal machining operations such as drilling, milling, turning, shaping, grinding, and sawing. In addition, you should know the basic steps involved in the removal and replacement of broken or damaged bolts, studs, and screws. Although you are not expected to be highly proficient at these operations, you *are* expected to try your best to complete each assigned task satisfactorily. As part of your training, you will most likely be assigned to assist skilled machinists in the performance of their tasks. Use such situations to your advantage by observing each operation attentively and by questioning those portions of the tasks that are not clear to you.

Even as a semiskilled machinist, you have responsibilities as well as duties. You have a responsibility to the Air Force to take an *active* interest in your training and to become productive (skilled) within the specified training time period. You also have a big responsibility to yourself to take *pride* in every job that you do, whether it is completing this CDC or cleaning and painting shop machinery. You will find that doing your best on the undesirable jobs, as well as on the more interesting ones, will make your job more satisfying and rewarding. It will also make it easier for you to attain your 5 skill level, which you must have to be eligible for promotion to senior airman (E-4), and will pave the way for future promotions.

Machinist. Since you are striving to attain the 5 skill level, a good understanding of the duties and responsibilities for that position is necessary. Therefore, it would be to your advantage to read carefully the specialty description for a machinist in AFR 39-1, *Airman Classification Regulation*. This description states that the machinist operates metal-working machines in fabricating, reworking, and repairing metal parts. By itself, this work is very similar to what an apprentice machinist is required to do. The difference is that the skilled machinist is expected to perform these operations proficiently with little or no supervisory aid. The specific duties and responsibilities of the skilled machinist include:

- Manufacturing and reworking machined parts.
- Assembling and fitting machined parts.
- Maintaining hand and machine tools.
- Supervising machine shop personnel.

A machinist must know how to use precision measurement tools; make and use drawings; and make work and tool setups on the drill press, lathe, grinder, shaper, milling machine, and contour machine. He must be able to use machinist charts and tables; make calculations; select cutting tools; select speeds and feeds; and perform various machine tool cutting operations, using the appropriate machine. He must know how to assemble and fit together metal parts and fasten them with machine screws, bolts, rivets, and press fits. He must also be able to remove burrs and projections, using handtools such as files, stones, chisels, and sheet abrasives. He must be able to perform various operations involving the use of an electric or hand drill, reamers, taps, and dies. He must know how to extract damaged studs, plugs, and pins; press bushings and bearings in place; assemble gears, shafts, and pins; install and level machines to insure accurate dimensions in machined work; and sharpen milling cutters, drills, reamers, tool bits, taps, and hand-cutting tools. Finally he must know how to determine the appropriate operation and what power or handtools are suitable for the job.

In addition to knowing how to perform the skills of the trade, the machinist has responsibilities in the areas of supervision and training, assigning work, evaluating performance, and demonstrating the use of tools and equipment.

As a 5 level, you could be called on to take charge of a special work detail involving several individuals or even to temporarily take over the operation of an entire shop. Also, you will probably have the responsibility of training other apprentice machinists to the 5 level. In other words, a skilled machinist has a responsibility to develop his sense of logic and reason, as well as the mechanical skills required to perform his varied duties.

Exercises (003):

1. List the two key responsibilities of an apprentice machinist.

2. List the four basic areas of duties and responsibilities for the 5-level machinist.

3. Briefly state the biggest difference in the responsibilities of the apprentice machinist (3 level) and machinist (5 level).

004. Given a list of duties and responsibilities, match them with the most appropriate skill level (7 skill level or 9 skill level).

Machine Shop Technician. The machine shop technician (7 skill level) designs and machines precision tools, parts, and assemblies; inspects machine work; and supervises machine activities. More specifically, his duties and responsibilities include the following:

- Advising on metal machining, design, and production problems.
- Inspecting in-progress and completed machine work for quality of workmanship and serviceability.
- Supervising metals machining techniques and maintenance of machinery and equipment.
- Supervising machine shop personnel.

The machine shop technician must know how to design and make precision tools, gages, dies, and jigs; calculate cutting speed for turning special threads; perform all types of difficult machining operations; and determine the repairability of machined parts, the need for heat treating, and the need for repair or replacement of gages, jigs, or dies. He must be able to determine whether or not machined parts conform to specifications and make precision measurements to insure the accuracy of dimensions. He must be able to instruct the personnel in his shop in work layout, in setting up lathes and other shop machines for various machining operating, and in machine adjustment and maintenance.

In his supervisory role, the machine shop technician supervises shop personnel in machine tool setup, in machine cutting operations, in hand operations, and in bench assembly fitting and adjusting of machined parts. He supervises the design and manufacture of precision tools, dies, and jigs, and the proper use and maintenance of machines. He assigns work and coordinates supply procedures and equipment requirements. He follows good maintenance and personnel management procedures. He coordinates work schedules with other affected shops and activities.

As you can see, the machine shop technician's job pertains less to the performance of machinist skills and more to advising, controlling quality, training, and supervising. The farther up the career ladder that you go, the more you will find increased emphasis on supervision and less on actually performing the machinist skills. The top positions of a career field are most effectively filled by personnel who have had actual supervisory experience. The gradual increase in supervisory responsibilities from the apprentice machinist to the fabrication superintendent is designed to provide that experience. Thus, as you move up the ladder, you are continually preparing yourself for the next higher position.

Fabrication Superintendent. Let's take a look now at the fabrication superintendent, AFSC 42799. The fabrication superintendent's job is to coordinate and supervise the work of the machine shop; metals processing shop; airframe repair shop; corrosion control shop; nondestructive inspection shop; and the fabrication and parachute shop. His duties and responsibilities are to:

- Plan and organize fabrication activities.
- Direct fabrication activities.
- Establish and conduct on-the-job training for fabrication personnel.
- Inspect and evaluate fabrication activities.
- Perform technical fabrication functions.

The fabrication superintendent plans workloads and work assignments, establishes production controls and work standards, and prepares and analyzes reports and graphs in the area of maintenance management. He establishes requirements for equipment and supplies and develops organizational charts to establish lines of authority and to assign specific responsibilities. He evaluates machine and hand-fabricating operations and directs the use, maintenance, and repair of machinery tools and equipment. He expedites work to meet estimated completion dates. He recommends personnel actions, such as reclassification, grade adjustment, and discipline; rates subordinates for efficiency; and reviews efficiency ratings made by supervisors. He directs a continuous program of on-the-job training for personnel at all skill levels. He reviews training charts to determine the status of training and determines the need for future training.

The fabrication superintendent tests new equipment and operates machines in fabricating new parts or reworking reparable components. He decides whether or not it is more practical to repair or manufacture parts and whether or not it is necessary to condemn parts or make material substitutions. He establishes and revises shop procedures to conform to directives received from higher authority.

Fabrication manager. Another 9-level position called fabrication manager has been established above that of fabrication superintendent. Figure 1-1 shows the fabrication manager's position and the grade spread applicable to it. Note that only those NCOs in the highest rank (chief master sergeant) will attain this position. The duties of the fabrication manager are basically the same as those for the fabrication superintendent, except that they are more general and are completely managerial. As shown in figure 1-1, this position is identified by a special AFSC (42700) called a *Chief Enlisted Manager (CEM)* code. The CEM position was added to the top of all major career field areas, and each is identified by its own special code. The purpose is to recognize the fact that an individual who proves himself by attaining the rank of chief master sergeant is capable of working in a variety of similar jobs and functional areas where his managerial abilities can be best utilized and challenged.

There is no assurance that you will eventually become a fabrication superintendent or a fabrication manager, even though you apply yourself with the utmost diligence to your job; but taking everything into consideration, a technician in the machinist ladder has as good a chance as the technician in any of the other ladders in the fabrication career field subdivision.

Exercises (004):

In the following, match the duties and responsibilities with the most appropriate skill level.

a. 7 skill level (machine shop technician).
b. 9 skill level (fabrication superintendent).

____ 1. Make in-progress checks of quality of workmanship.
____ 2. Develop organizational charts to establish lines of authority.
____ 3. Instruct in machine maintenance.
____ 4. Directly supervise shop personnel in designing and manufacturing precision tools, dies, and jigs.
____ 5. Determine validity of proposed disciplinary actions.

serious injuries, and even fatalities can occur when people try to extinguish fires by themselves without calling the fire department. By the time they realize that they can't handle the fire, it is too late for them, the property, or both!

Exercises (017):

1. Why is a 50-foot NO SMOKING area established around areas where flammable liquids are in use?

2. How should soiled rags be contained while in a shop?

3. What type of extinguisher should be used on electrical fires?

4. What should be used on a magnesium or titanium fire?

5. What action is essential whenever a fire occurs?

3-2. Flight Line Safety

Too often, safety is forgotten when a machinist heads for the flight line. There are several reasons (inexcusable though they may be) for this: there is usually no supervisor around to enforce safety standards, the machinist is usually pressured to complete line work quickly, weather conditions make extended stay time uncomfortable, etc. The flight line can either be one of the most dangerous places in the world or one of the safest, depending entirely on how you and others observe established safety precautions and practices. Let's review some of those precautions.

018. Describe hazards and state safety precautions pertaining to flight line operations.

Clothing and Protective Equipment. The Air Force has developed protective clothing and equipment for flight line operations based, again, on years of experience. Probably the most important pieces of this equipment are earplugs and muffs. A person's ears can be permanently damaged much easier than most people think. Working around an operating jet engine or certain turbine and gas-powered pieces of aerospace ground equipment (AGE) without ear protection can easily cause gradual damage to a person's ears without the person's realizing it until it's too late. You should have earplugs and/muffs *every* time that you go to the flight line. Be sure to wear them.

Bases in colder climates have a special hazard to contend with during the winter months: cold temperatures! In these areas, you should wear the extra winter gear that is provided. Granted, it is usually bulky and prevents the freedom of movement that you are normally used to, but it's much better to do the job a little slower than to go back to the shop with frostbitten ears, fingers, or toes. Frostbite is extremely painful and can result in amputation of the affected area.

Hot climates also have certain weather hazards. When the temperature soars to 90° and above, metal surfaces on the flight line become much too hot to touch. If you must work on top of an aircraft under these circumstances, you should always sit or kneel on a padded cushion instead of the metal surface. Aircraft surfaces can become so hot that even prolonged standing on them is impossible. Also, the possibility of sunburn and heatstroke is greatly increased due to the fact that the heat is radiated off the surface as well as directly from the sun. This is no place to try to get a suntan; keep that shirt on! It may be uncomfortable, but it will keep you from suffering a painful burn. Take short breaks periodically and get into some shade to prevent sunstroke.

Aircraft and Equipment Hazards. The temperature and velocity of the exhaust gases behind an operating jet engine are great enough to cause serious injury. The temperature of the exhaust gases 25 feet behind one of the smallest engines, the J-69, installed in the T-37 training aircraft, exceeds 350° F. The velocity of the exhaust gases is another hazard. As a general rule, the minimum safe distance behind an operating engine is 200 feet; for the F-4, it is 250 feet. Blast fences help reduce the safe distance. A jet engine uses a large volume of air. All of this air is taken into the intake. The suction developed immediately in front of the engine is enough to pull caps, coats, or men into the engine. The minimum safe distance in front of the engine is 25 feet. Do not approach closer than 5 feet to the duct entrances from the side or rear. All objects must be removed from the area in front of the ducts before the engine is started.

The area in line with the plane of rotation of the turbine wheel must be kept clear. If a wheel should suddenly disintegrate when the engine is running, the pieces can be thrown a long distance. Standing directly in line with a turbine wheel is like looking down the barrel of a loaded and cocked rifle. The same precautions apply to the turbine wheels of pneumatic or combustion (fuel-air) starters. They turn at a very high rate of speed and are extremely dangerous. The turbine wheel danger area of the later model jet engines and turboprop engines are much larger, since they use multistage turbine wheels.

Turboprop engines are used on some of the cargo aircraft, such as the C-130. The propeller is dangerous if proper precautions are not observed. Many persons have been seriously hurt or killed by propellers. The main reason for these injuries is that propellers become almost invisible during run-up operations. People walk into them without ever seeing them!

As we stated before, the high-frequency sound of modern jet engines can cause you to become completely deaf. It can also cause severe mental health damage. Prolonged exposure to this noise can cause nervous tension to build up to the breaking point (another excellent reason to wear those earplugs!) The noise level of a 5,000-pound thrust turbojet engine can cause pain. A larger turbojet with afterburner can cause not only pain but physiological symptoms. A good example of high noise level is the F-4 aircraft, which uses the 15,000-pound thrust J-79 engine. The danger area extends over 1,600 feet behind the aircraft as well as sizable distances in front of and to the side of it.

Most hazards can be avoided by simply paying attention to what you are doing. Remember, most accidents are caused by carelessness. Here are a few other flight line precautions:

a. Install guard rails, especially on high stands.

b. Install the safety pins on all hydraulically operated work stands before you use the stands.

c. Keep tools in your box when not in use. A loose tool on a stand can cause a serious fall.

d. Do not place toolboxes in a position where they can fall and hurt someone.

e. Be careful working around the trailing edges of the wing and control surfaces. These edges are sharp. The leading edge of the wing on some aircraft, such as the T-38, is just as sharp.

f. Do not work in the flap or speed brake area until you are sure that these controls cannot be operated.

g. Be sure that the aircraft static grounds are installed and in good condition.

h. Do not wear jewelry or a wristwatch while you are working. They can catch on sharp surfaces and seriously injure you.

i. When operating pneumatic equipment on the flight line, be sure that the air pressure in the lines does not exceed 150 psi. Never hook into a high-low stage compressor (high-pack) to operate pneumatic tools: a malfunction in the unit could release enough air pressure to literally explode the tool in your face or rupture the hose, causing it to whip wildly. Use only the single-stage compressor (low-pack) and check the pressure setting.

Radiation Hazards. Because of the new sophisticated materials used in aircraft and certain specialized metal inspection techniques, the problem of radiation exposure is becoming more pronounced each day. Radiation is such a serious health hazard that elaborate precautions are taken in the Air Force to guard against even accidental exposure. Since you cannot see radioactivity, several hours may elapse after exposure before you feel any effects; therefore, you must be able to instantly recognize radiation warnings. The primary purpose of the various AFTO Form 9 warning signs is to guard against gamma radiation.

Figure 3-1 shows one of the radiation warning placards. All radiation signs display the distinctive three-bladed magenta-colored insignia against a yellow background with black block type. The warning signs are designed to attract immediate attention. Each sign is designed for a specific purpose, and the exact size for most of them is specified by technical order. The AFTO 9 series forms are listed below:

- AFTO Form 9, Caution Radioactive Material (radioactive material warning placard, 8½ x 11 inches). This placard is used in areas where radioactive materials are stored in such a way that the radiation intensity at 1 foot from any single container is in excess of 2 milliroentgen hours (mr/hr) but less than 100 mr/hr. This is the placard that you would most likely encounter around areas where the NDI shop is using X-ray equipment.
- AFTO Form 9B, Radioactive Material Warning (Label). This is a flexible but durable gummed label. A sufficient number of labels are attached to insure that one is visible from any direction of approach.
- AFTO Form 9C, Caution Radioactive Material (radiation area warning placard, 8½ x 11 inches). These placards are posted in conspicuous places. They indicate that the radiation intensity at 1 foot from any container exceeds 1 mr/hr but is less than 100 mr/hr.

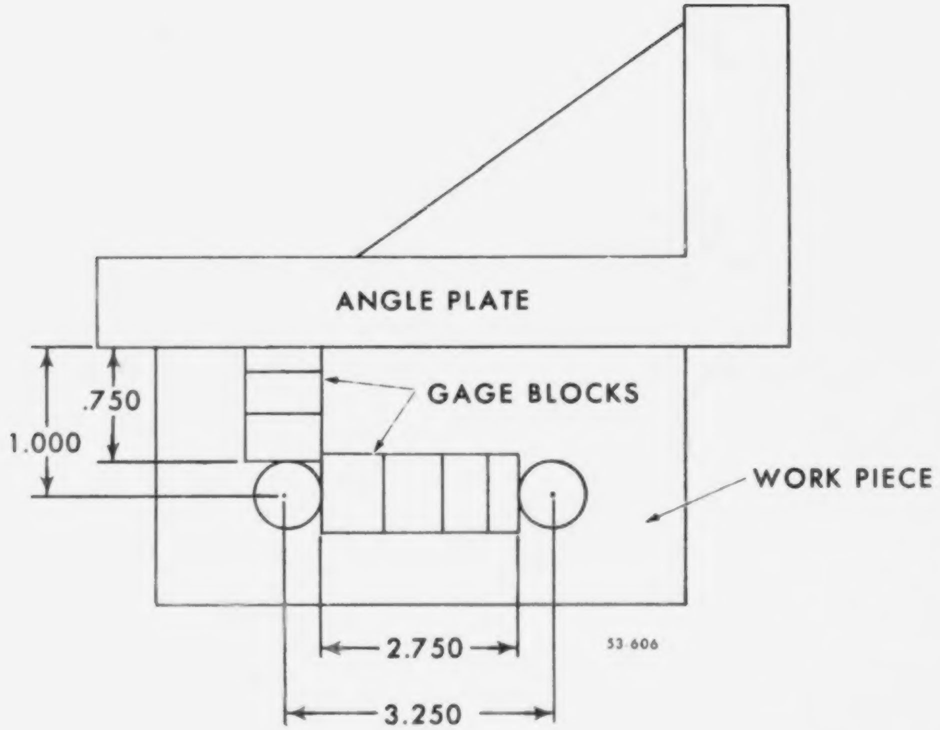


Figure 5-24. Setup for toolmaker's buttons.

The micrometer measures across the buttons; therefore, you must remember to *subtract* one-half the sum of the diameter of the buttons from the *micrometer reading* to obtain the true center distance. The gage blocks may be used to check the edge distance of the second block. When you have the second button located, tighten the retaining screw securely.

After the first button in a series of holes in line is properly located, you can use a dial test indicator to set the edge distance of the other holes in the line. After repeated checking of the locations of the buttons, check to insure that they are secure to the work. Make a final check of the button locations after the screws are tightened. You now have the holes accurately laid out with the toolmaker's buttons. The part is ready for the boring operation.

If the part is to be bored in a lathe, you mount the part on a face plate. You locate the part by using a dial test indicator on the buttons. When you have the button centered to within tolerances by lightly tapping the work, tighten the clamps securely. Recheck the reading after securing the work. You then remove the button and drill and bore the hole to specifications. Repeat the centering of the buttons for the remaining holes and bore them to specifications. If you perform these operations carefully, you will be able to drill and bore holes with very accurate locations.

Exercises (041):

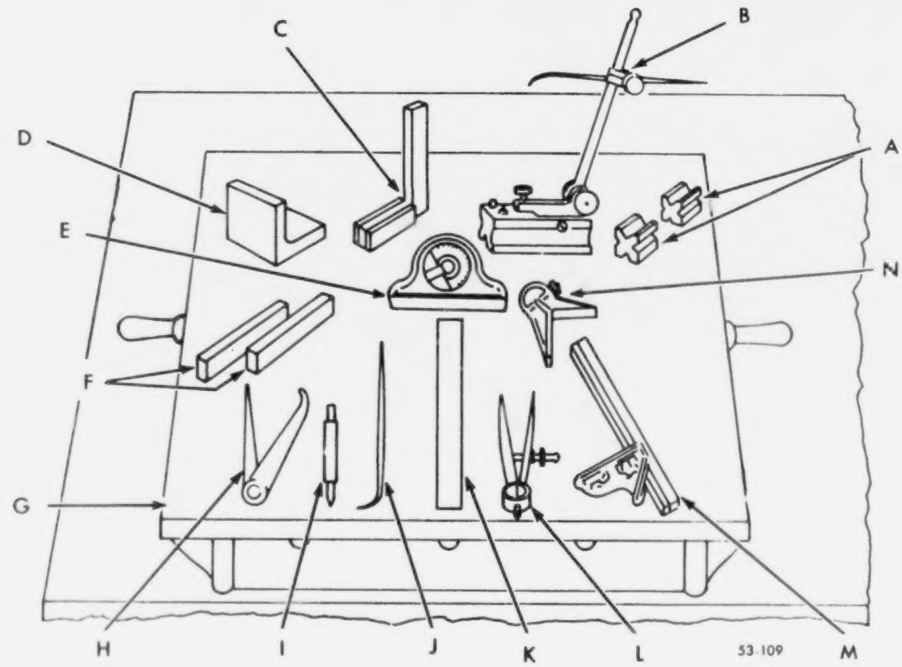
1. Why is one button in a set of toolmaker's buttons usually longer than the others?

2. If you have hole centers located by layout lines, why would you use toolmaker's buttons?

3. If you were required to locate two holes 2.375 inches apart and you were using 1/2-inch diameter buttons, what amount of gage blocks would be required between the buttons?

4. If you had to use an outside micrometer instead of gage blocks to check the button locations indicated in exercise 3, what would the micrometer reading be when the buttons were set properly?

5. After you have accurately located the buttons on the work, how could you insure that a particular



A. V-blocks
B. Surface gage
C. Toolmaker's square
D. Angle plate
E. Protractor head
F. Parallels
G. Surface plate
H. Hermaphrodite caliper
I. Center punch
J. Scribe
K. Rule
L. Dividers
M. Square head and blade
N. Center head

Figure 5-25. Common layout tools.

hole will be accurately aligned on a face plate of a lathe for a boring operation?

5-4. Layout Work

You will be required at times to lay out work prior to machining it. Laying out the work is planning the work on the surface of the material. It is the scribing (marking) of lines that indicate the boundaries, centers, and other locations on the object so that you are able to machine it to the desired size and shape. The care with which you do layout will determine the accuracy of the finished work.

042. Explain various layout procedures and indicate specific tools and equipment used in the process.

Layout Compound. To lay out work, you scribe lines on a layout compound that has been applied to the surface of the work. A commercial layout blue dye is most often used. This is a liquid that dries rapidly, leaving a glare-resistant dark blue film on the work. Lines scribed through this film show up distinctly. Since the fluid evaporates rapidly, you should keep the container tightly closed when you are not using it. Apply a thin coating because the compound tends to flake or produce ragged lines when it is applied too heavily. Common chalk is often used to lay out rough finished surfaces. Regardless of the type of compound that you use, keep the surface clean and free of oil, and remove all burrs with a file or oilstone to prevent inaccurate measurements and possible injury.

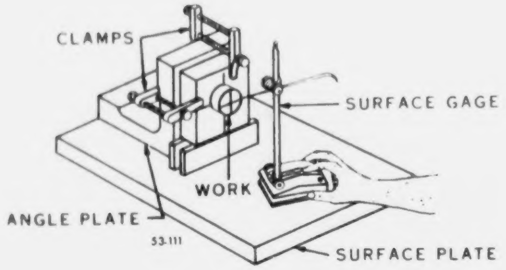


Figure 5-26. Use of the angle plate and height gage.

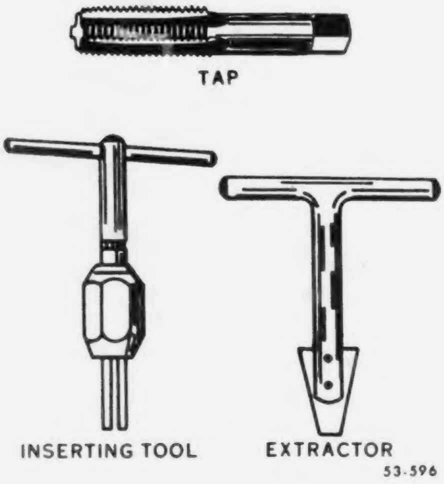


Figure 6-22. Heli-Coil handtool set.

The seat for lock-ring inserts is prepared in much the same way as for flanged inserts, except that the counterbore for the ring is deeper than the thickness of the ring. This difference is necessary to provide clearance for the burrs created under the ring when the serrations on the outer diameter of the ring cut into the parent metal during installation. The ring should be installed flush with the parent surface, but the insert should be a few thousandths of an inch below the parent surface.

No special tools are required to thread a solid insert into a prepared seat. Usually a bolt and a nut can be used, as shown in figure 6-21.

Solid Insert Removal. Removing a solid insert is usually more difficult than installing it. To remove a flanged or straight insert that is secured by a dowel type lock-pin, you must first remove the pin. Although pin removal is normally accomplished by drilling the pin out, this method is difficult because the pin is so small in diameter and is usually made of a tougher material than the parent metal. However, once the lockpin is removed, the insert will usually come out quite easily by using a stud extractor.

To remove an insert of the lock-ring type, drill the neck of the insert to a depth just below the bottom of the ring, using a drill at least as big as the minor diameter of the serrations on the insert. This action will free the insert from the lock-ring and will allow you to pry the ring out of the parent metal. Once the ring is removed, the insert usually can be removed without difficulty by using a stud extractor.

When the threads in the parent metal of a solid insert seat are damaged to the extent that the seat cannot be used again, the part will normally have to be condemned and replaced. Therefore, it is imperative that you be extremely careful to protect the parent threads and other seat surfaces when you remove a solid insert.

Exercises (055):

1. Why is the depth of the counter-bore considered critical for a flanged solid insert?

2. How does the top surface of a properly installed solid insert compare with the surrounding surface of the parent metal?

3. Why is the depth of the counterbore for a lock-ring insert deeper than the thickness of the ring?

4. What tool is normally used to thread a solid insert into the parent metal?

5. Why is insert removal usually more difficult than insert installation?

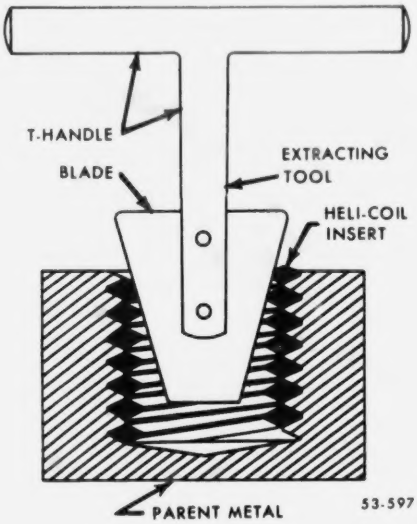


Figure 6-23. Use of the Heli-Coil extracting tool.

6. Explain how to remove the lock-ring when a lock-ring insert must be removed.

7. When you must remove a solid insert, why should you be *especially* careful not to damage the parent threads?

056. Explain the installation and removal procedures for Heli-Coil inserts.

Heli-Coil Insert Installation. The use of Heli-Coils requires some special tools, the most important of which is the tap (see fig. 6-23). Each size of Heli-Coil insert has its own special tap. Also, each Heli-Coil size has a particular size of inserting tool. The standard inserting tool prewinds the Heli-Coil (compresses it to the same size that it will be when installed) in a threaded tubular portion, and a slotted center shaft is used to wind the insert into the parent threads. If your shop does not have a Heli-Coil tap drill chart, you can obtain this information, as well as other information about the use of Heli-Coils, from Technical Order 44H1-1-117, *General Installation of Heli-Coil Inserts* of from TO 1-1A-8, *Structural Hardware.*

There are several important things to remember in installing Heli-Coils. You should always use the correct tap drill size for the size of Heli-Coil that you are installing. Some Heli-Coil taps come in two sizes, roughing and finishing, and are marked as such on the tap shank. If you rough-tap the hole and install the Heli-Coil, the screw or bolt will not screw into it. Therefore, be sure that you use a finishing tap before installing the Heli-Coil. Also, the Heli-Coil should be installed so that the top coil is approximately a half turn below the parent surface. This distance insures that the top coil is seated in a full thread groove and helps to prevent the Heli-Coil from stripping out.

After installing the Heli-Coil, you must remove its drive tang. There is a special tool called a tang breakoff tool that you can use. If a tang breakoff tool is not available, you can use a drive pin punch and hammer. The drive pin punch should be slightly smaller than the minor diameter of the Heli-Coil. If the minor diameter of the Heli-Coil permits, a pair of long-nosed pliers can be used to break the tang off. You should never use the inserting tool to break off the tang, because the tool could break or the bottom thread of the Heli-Coil could be damaged. If the Heli-Coil or its broken off tang is accidentally dropped into an inaccessible area, you can use a small magnet to retrieve it. When you break a tang off in a blind hole, it can easily be removed by placing a small spot of grease on the shank end of a small drill bit and then placing the greased drill bit in contact with the tang. The tang will adhere to the grease and can be lifted out of the hole. Never leave the tang in the hole after it is broken off; it could cause the bolt or stud to be stripped during installation.

Heli-Coil Insert Removal. Removing a damaged Heli-Coil is a fairly simple matter. Figure 6-23 shows how a standard Heli-Coil extractor is used. Each extractor tool has a certain range of insert sizes that it can be used on (usually marked on the tool). Before you attempt to remove the insert, check to see whether the parent metal has been dimpled in front of the top thread of the Heli-Coil. If it has been, you must remove whatever metal is blocking the insert thread before the insert can be efficiently removed. The extractor should be inserted into the holes so that one side of the blade is a quarter-turn from the end of the top insert coil. Strike the head of the tool *lightly* with a hammer. This causes the edges of the extractor blades to dig into the top coil of the insert. After the blade has been properly seated in the coil, you should apply heavy hand pressure on the handle of the tool and turn it slowly counterclockwise. Maintain a firm pressure as the insert backs out. A stud extractor made from a tool bit can also be used to remove a Heli-Coil insert when a standard extracting tool is not available.

NOTE: Never pull a Heli-Coil insert straight out with a pair of pliers. This practice can damage the parent threads to the extent that they cannot be used again.

Exercises (056):

1. What three tools are normally required for Heli-Coil installation?

2. Which of the three tools referred to in exercise 1 is the most important?

3. What can be used in place of a standard tang breakoff tool?

4. How should the Heli-Coil extractor tool be seated for insert removal?

CHANGES FOR THE TEXT: VOLUME 2

Pen-and-Ink Changes:

Page-Col.	*Subject*	*Lines*	*Correction*
Front Cover			Change "(AFSC 53150)" to "(AFSC 42750)."
5R		6	Change to read "Military Specification Number or National Stock Number."
5R		25,26	Change the sentence beginning with "The Federal . . . ." to read "The NSN or MIL number should . . . ."
9R		15	Delete "and" between "copper" and "manganese."
12L		last	Change "cores" to "core."
13R	207-6	2	Change "enter" to "center."
14R		10	Change "brough" to "brought."
18L		5 fr bot	Insert "other" between "any" and "type."
23R		18 fr bot	Change "Cast is usually" to "Cast iron is usually . . . ."
26L		26 fr bot	Change second "feed" to "speed."
26R		6	Change "fine-pitches" to "fine-pitched."
27L		7 fr bot	Change "blade" to "band."
27R		9	After "cutoff" insert "saw."
32R		6 fr bot	Insert "soft" between "as" and "aluminum."
37R		24-26	Change sentence to read "Also, the application of graphite powder to the band guide will lubricate the band and reduce its tendency to fray or tear."
38R		7	Change "wheels" to "wheel."
38R		11	Change "tile" to "tilt."
43L		23 fr bot	Insert "band" between "polishing" and "as."
43R		2	Insert "also" between "work" and "presents."
43R		15 fr bot	Change line to read "keeper block for mounting the lower saw guide. When."
44L		16 fr bot	Change "laesponds" to "layout corresponds."
44R		23	Change "rathern" to "rather."
45L		16 fr bot	Change "SFS" to "fpm" in two places.
46L		26	Delete "are required" and add a period after previous line.
46L		16 fr bot	Change "picot" to "pivot."
47R		6	Change "graduate" to "graduated."
48L		9	Change the comma to "of."
52L		1	Change the semicolon to "bit:"
52L		9	Change the second "the" to "to."
52L		11	Change line to read "end that prevents the drill bit from revolving in the drill press spindle."
52R		7 fr bot	Insert "include" between "drills" and "sizes."
55R		27 fr bot	Change "hand drill" to "hand drill motor."
55R		24 fr bot	Delete "hand" from beginning of line.

Page-Col.	*Subject*	*Lines*	*Correction*
57L		4 fr bot	Change line to read "The taper automatically aligns the tool."
57R		2 fr bot	Change ", and that" to "end."
58L		5	"lose" to "work loose."
61L		22 fr bot	Insert "flat" between "and" and "belt."
61R		1	Insert comma after "figure 4-2" and add "use V-belts and pulleys. They . . . ."
61R		6	Change "unpositioned" to "repositioned."
62L		3 fr bot	After "the flute)" add the following "of the same diameter as the hole."
62L		last	Change "drilled" to "reamed."
63L		17	Change "you" to "your hand."
65L		9	Change "toolholder" to "standard lathe toolholder."
65L		18 fr bot	Change "angle" to "positive angle."
65L		16 fr bot	Change "grind an" to "grind a negative."
72L		2 fr bot	After "ring" add "or plug."
77R		6	Insert "amount of" between "the" and "taper."
78L		2	Add "drag" at the end of the line.
78R		18,19	Change "are in alignment" to "remain in alignment when the taper attachment is used."
91R		15,16	Change the formula beginning with "Depth = ..." to read "Depth = $(1/2 \div N) + 0.010$ inch $= \left(\frac{0.500}{N}\right) + 0.010$ inch, as shown in figure 5-47."
92L		15	Change "threads and a square thread" to "V-threads and square threads."
94L	Formula		Change to read as follows: $\frac{A \times B}{C} = X, \ \frac{32 \times 27}{24} = 36$
99R	1	1	Change "a definite distance" to "with a definite distance or space."
108L	235-3	4	Change "accuated" to "actuated."
109L	246-1	1	Change answer to read "By reducing the feed pressure."
109L	246-3	3,4	Change "145" to "140" and "290" to "280."
110R	257-3		Change answer to read "It decreases."
110R	261-2		Change answer to read "The feed is too fast or there is too much back rake on the parting tool."

Page Changes: Remove old pages and insert new pages as indicated. If the replacement pages number more than those they replace, those pages in excess of the pages being replaced will carry letter designations. For example: 20, 20a, 20b, etc.

Remove Pages	*Insert Pages*
iii-vi	*iii-vi*
15-16	15-16a
33-36	33-36
41-42	41-42a
53-54	53-54
59-60	59-60
73-74	73-74a
83-90	83-90a
101-104	101-104
111-112	111-112

Preface

THIS SECOND volume of CDC 42750, Machinist, covers metallurgy and advanced machine work. Chapter 1 is a brief study of the characteristics and uses of metals. You will need this information in almost every aspect of your job as a machinist. As you work with metals and machines, you will also quickly recognize the need for machine lubricants, cutting fluids, and coolants. This is what Chapter 2 is all about. Chapter 3 begins our study of the various machines that you will operate, beginning with power cutoff machines. Chapter 4 deals with drill presses, and Chapter 5 covers lathes and press work.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: Tech Tng Cen/TTGXW, ATTN: SMSgt John D. Wurm, Chanute AFB IL 61868. If you need an immediate response, call the author, AUTOVON 862-2385, between 0800 and 1600 (CST), Monday through Friday. *(NOTE: Do not use the suggestion program to submit changes or corrections for this course.)*

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this person can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of July 1981.

Acknowledgment

THE ITEM listed below has been reproduced by permission of the following:

Figure 3-2	Johnson Manufacturing Corporation, Albian, Michigan 49224

Contents

Page

Preface . . . . *iii*

Acknowledgement . . . . *iv*

Chapter

1 Metallurgy 1

2 Lubricants and Coolants 17

3 Power Cutoff and Contour Machines 25

4 Drill Press Work 50

5 Lathe and Press Work 64

Bibliography 104

Answers for Exercises 105

2. What does the term "solution heat treatment" mean?

3. Briefly explain "precipitation hardening."

4. What does "temper" mean in reference to aluminum?

5. An aging process for aluminum alloys that freezes the internal changes that would normally occur is known as ______________________________ .

6. Various magnesium alloys may respond favorably to how many of the various nonferrous heat treatments?

7. How are copper alloys usually hardened?

8. What effect does heat treatment (other than annealing) have on titanium?

1-4. Testing for Hardness

When a machinist must modify metal parts or equipment, he must know the hardness of the metal if he is to determine the proper tools and the proper machining steps that will be involved. Determining the hardness of metal can involve the use of a simple handtool when great accuracy is not required or it can involve more complicated and more accurate equipment. The next objective will briefly cover the most common types of hardness testing.

209. Describe the common types of hardness testing, and explain the use of the Rockwell hardness tester.

File Test. One simple way to check for hardness in a piece of metal is to file a small portion of it. If it is soft enough to be machined with regular tooling, the file will cut it. If it is too hard to machine, the file will not cut it. You can use the file in the same way to determine the hardness of two pieces of metal; the file will cut the softest metal easier. When you use the file to check for hardness, be careful not to rub your fingers or hands on the file face or the work piece. The acid and oil from your hands can cause the file to slide over the work instead of cutting it. If that happens, it can easily be mistaken for a sign that the metal is too hard to cut with the file. At any rate, the file method should only be used in situations when the exact hardness is not required. Normally, when accuracy is required, you must take the part to the metals processing shop, where it can be checked with a Rockwell hardness tester.

Rockwell Hardness Tester. A machinist does not normally perform hardness testing with the Rockwell tester since it is a responsibility of the metals processing shop; however, you should have a basic understanding of how the Rockwell tester works. The principle of Rockwell hardness testing is based on the distance that a penetrator will penetrate a piece of metal.

There are other types of hardness testers available (Brinell, for instance), but the Rockwell tester is the most common type in the Air Force. It has been selected by the Air Force because it is simple to operate; it can test a great variety of metals of varying degrees of hardness; and it does not depend upon the judgment of the operator for accuracy. Figure 1-7 illustrates a Rockwell hardness tester. Before any material can be tested for hardness, the proper anvil and penetrator (also called a brale) must be selected (fig. 1-8). The shape of the part to be tested will determine which anvil to use, while the type of material will determine which penetrator to use. The penetrator can be either a diamond or a hardened steel ball. The diamond has a sphero-conical shape (a cone with a rounded point) and is precision cut and polished. It is used for checking most ferrous metals and some harder nonferrous metals. The steel ball penetrator is normally 1/16 or 1/8 inch diameter, although penetrators with 1/4 and 1/2 inch diameters are available for some special tests. The ball penetrators are used mostly on nonferrous metals and other materials that are relatively soft.

The Rockwell tester uses the static principle (exerting force by reason of weight alone without motion)

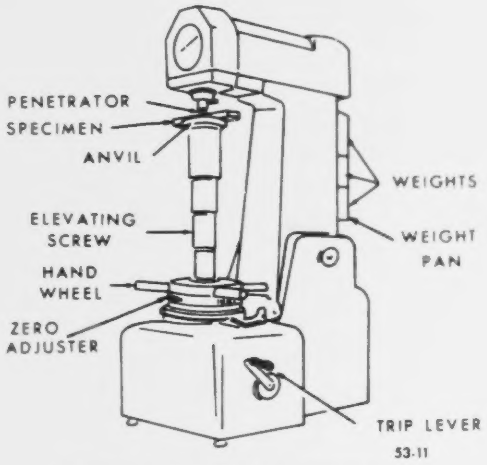


Figure 1-7. Rockwell hardness tester.

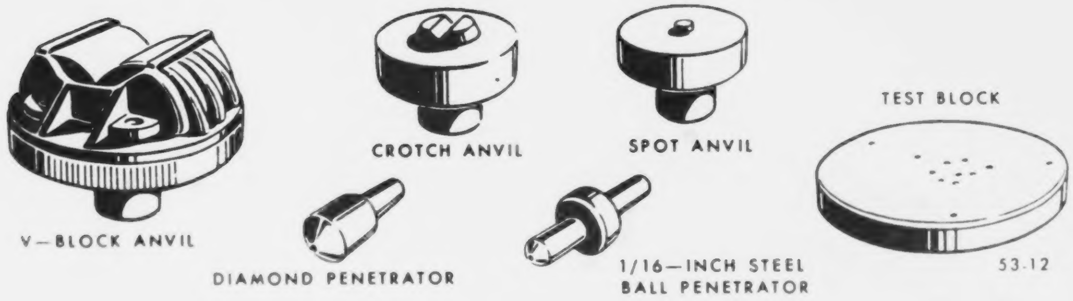


Figure 1-8. Rockwell hardness tester attachments.

and works on the leverage system. When the lever shown on the right side of the base in figure 1-7 is tripped, a predetermined load or weight forces the penetrator into the metal being tested. The hardness value, which is determined by the distance that the penetrator travels into the test specimen, is indicated on the dial. The shallower the penetration, the higher the hardness number.

There are two stages to making a hardness test with the Rockwell tester. During the first stage, the "minor load" is applied. It is used to securely lock the test specimen in place to prevent slipping. During the second stage, the "major load" is applied. It is during this stage that the machine measures the distance that the penetrator travels into the test specimen and converts it to a hardness value.

As we stated, the minor load must always be applied first. When it is applied, a load of 10 kilograms (approximately 22 pounds) is applied to the penetrator. The minor load is always 10 kilograms, regardless of the major load or penetrator used. Once the minor load has been applied, it locks the test specimen in place. Only then can the major load be applied. The major load is also measured in kilograms and can be 60 kilograms (132 pounds), 100 kilograms (220 pounds), or 150 kilograms (330 pounds), depending upon the material being tested. When the major load is applied, the needle in the dial indicator will begin to move. After the needle movement has stopped, the major load is removed. The needle will then move to the position on the scale which indicates the hardness value of the material being tested.

The dial face of Rockwell tester (fig. 1-9) contains several different scales. The "C" scale is used with the diamond penetrator for testing hardened steels. The "B" scale is used with the 1/16-inch steel ball penetrator for testing soft or annealed steel and some harder types of nonferrous metals. The "E" scale (not shown in figure 1-9) is used with the 1/8-inch steel ball for general nonferrous testing. In each case the major load is set at a certain weight for each particular scale to be used. These are the most commonly used scales; however, there are several others, depending on the major load and penetrator that is used. For this reason the scale designation should be given with Rockwell hardness members; for example, "Rockwell 50C" shows that the "C" scale was used. Technical Order 1-1A-9, *Aerospace Metals,* gives detailed information on hardness testing of metals.

This concludes our chapter on metallurgy. In our next chapter we will discuss various lubricants and coolants and their applications in the Air Force machine shop.

Exercises (209):

1. How can you quickly determine the approximate hardness of a metal?

2. When testing for hardness with a file, why shouldn't you handle the file face with your bare hands?

3. Who will normally perform hardness testing on the Rockwell tester?

4. What is the name and shape of the diamond penetrator?

5. What is the purpose of the minor load?

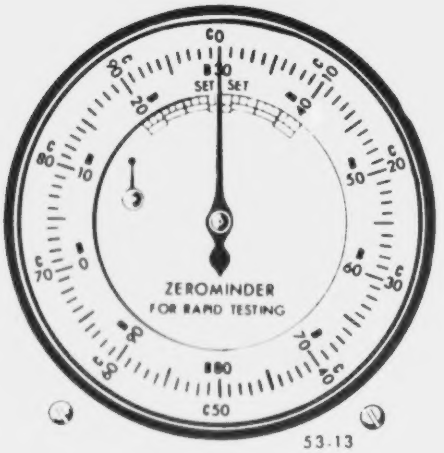

C0
B30
SET SET
ZEROMINDER
FOR RAPID TESTING
B80
C50
53-13

Figure 1-9. Dial face of a Rockwell hardness tester.

6. Normally, what scale and penetrator should be used to check hardened steels with the Rockwell tester?

7. Which penetrator should be used for checking soft or annealed steel?

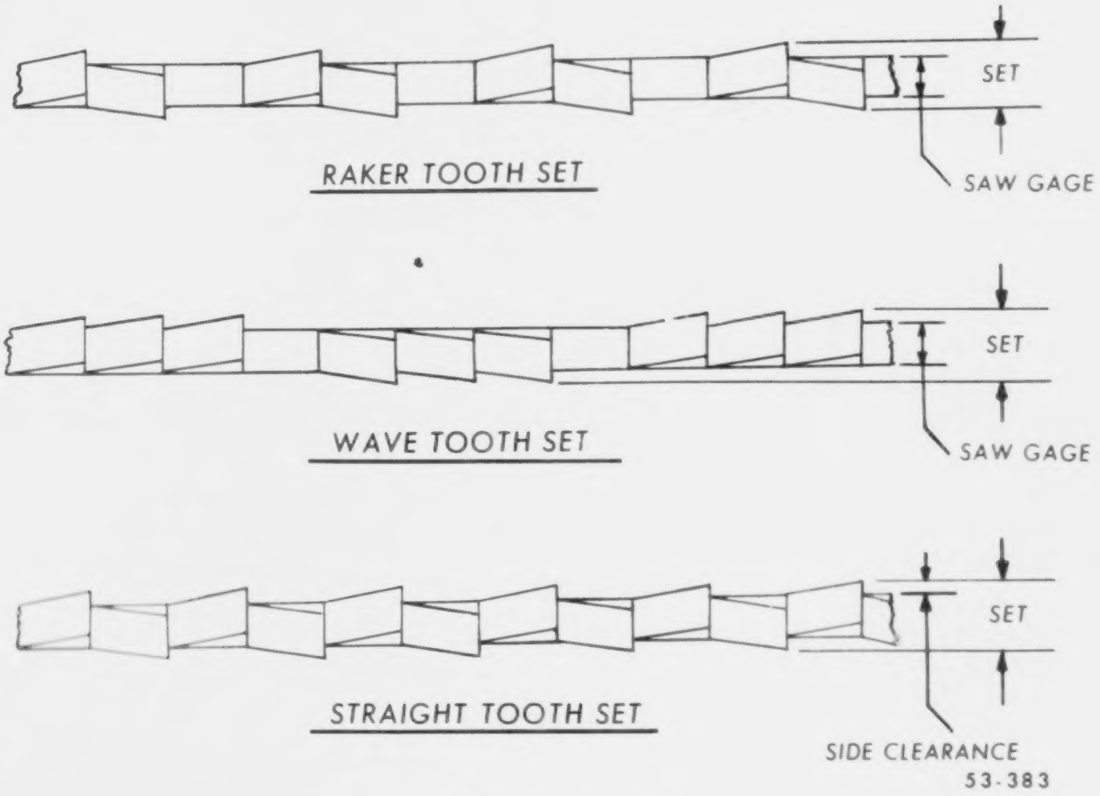

SET
SAW GAGE
RAKER TOOTH SET
SET
SAW GAGE
WAVE TOOTH SET
SET
STRAIGHT TOOTH SET
SIDE CLEARANCE
53-383

Figure 3-6. Set patterns.

The faster the saw speed and the finer the saw pitch, the finer the finish. Lubricating helps to improve the finish. A fine saw pitch, high velocity, and light feed produce the finest finish.

- Too fine a saw pitch for the work thickness causes a loading action in the gullets of the saw teeth. A lubricant will help correct this, but it is best to use the coarest pitch that will give the finish desired.
- For materials that are tough and stringy, such as brass, copper, and wrought iron, it is

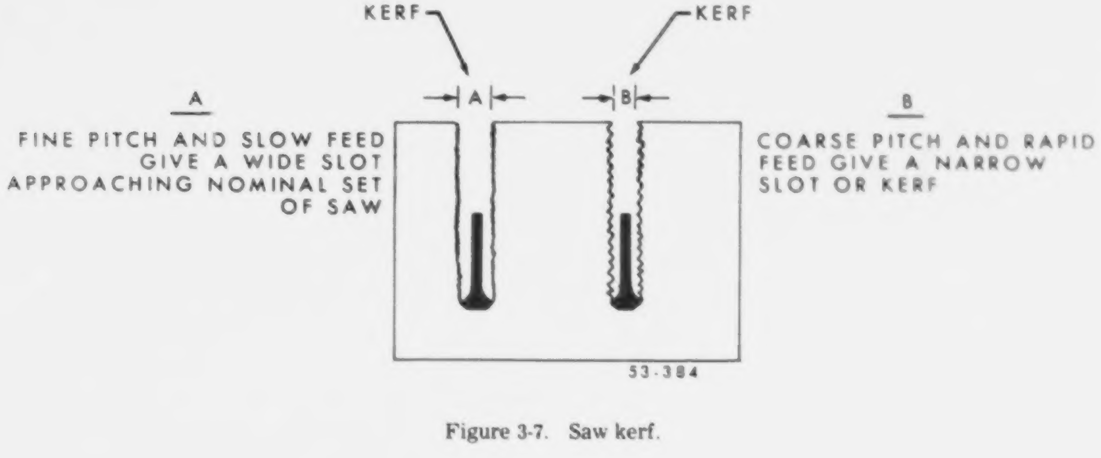

KERF
KERF
A
FINE PITCH AND SLOW FEED GIVE A WIDE SLOT APPROACHING NOMINAL SET OF SAW
A
B
B
COARSE PITCH AND RAPID FEED GIVE A NARROW SLOT OR KERF
53-384

Figure 3-7. Saw kerf.

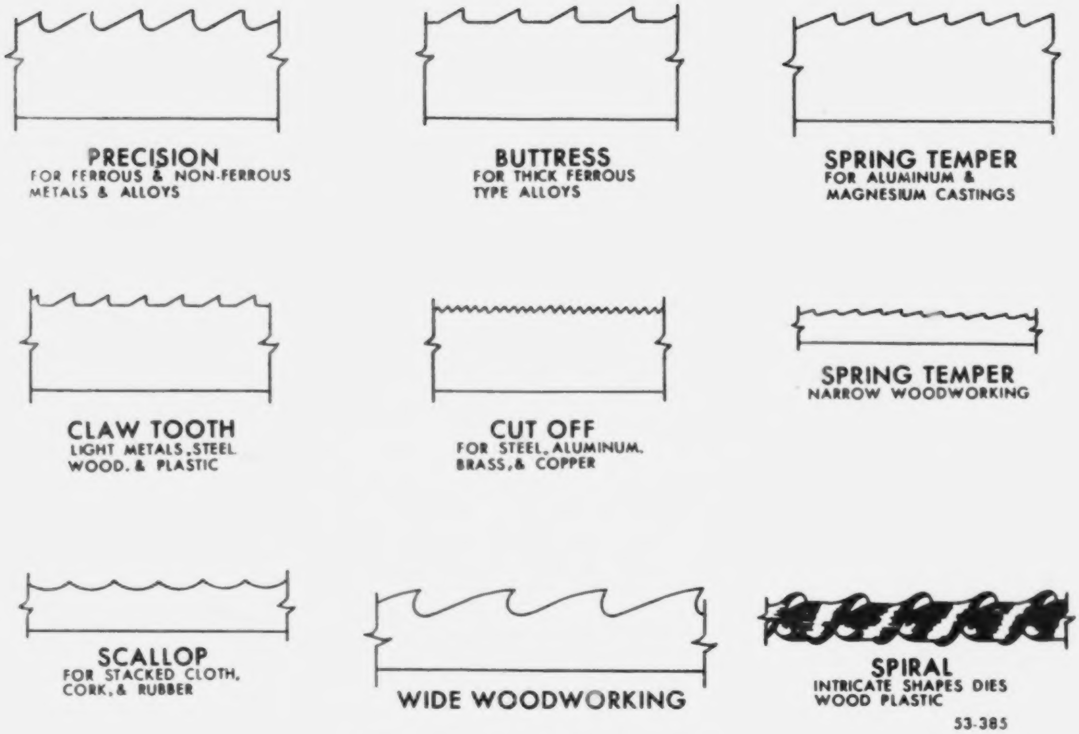

PRECISION
FOR FERROUS & NON-FERROUS METALS & ALLOYS
BUTTRESS
FOR THICK FERROUS TYPE ALLOYS
SPRING TEMPER
FOR ALUMINUM & MAGNESIUM CASTINGS
CLAW TOOTH
LIGHT METALS, STEEL WOOD, & PLASTIC
CUT OFF
FOR STEEL, ALUMINUM, BRASS, & COPPER
SPRING TEMPER
NARROW WOODWORKING
SCALLOP
FOR STACKED CLOTH, CORK, & RUBBER
WIDE WOODWORKING
SPIRAL
INTRICATE SHAPES DIES WOOD PLASTIC
53-385

Figure 3-8. Shapes of saw band teeth.

best to use coarse-tooth bands. Fine-tooth bands are better for harder, less stringy materials and steel.

- The set prevents the band from binding. It provides a clearance which makes radius cutting possible. It is the difference between the set of the saw and the gage that enables the band to turn in a cut, as shown in figure 3-9. The amount of set determines the width of the kerf and the amount of material removed by the band. The narrower the kerf, the less feed pressure and the less power will be required for sawing.

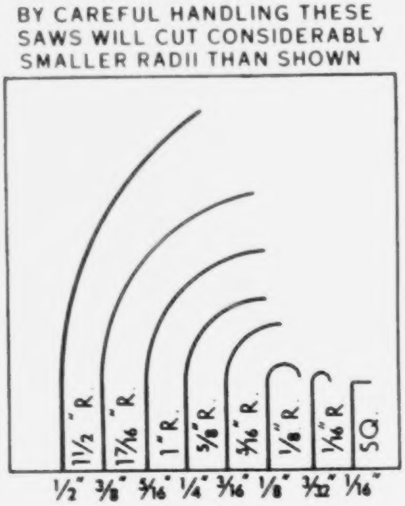

BY CAREFUL HANDLING THESE SAWS WILL CUT CONSIDERABLY SMALLER RADII THAN SHOWN
1½" R.
1⁷⁄₁₆" R.
1" R.
⅝" R.
⁵⁄₁₆" R.
⅛" R.
¹⁄₁₆" R.
SQ.
½"
⅜"
⁵⁄₁₆"
¼"
³⁄₁₆"
⅛"
³⁄₃₂"
¹⁄₁₆"

Figure 3-9. Saw band selection for various radii.

- When you cut irregular shapes you must consider the set. The wider the set, the wider the kerf and the easier it is to saw irregular shapes, since the band has more clearance in which to be turned.
- For very gummy materials, a coarse-tooth band should be used.
- The recommended pitch for various types of material is given below:

Pitch	*Material*
8	Large solid sections over 2 inches thick.
10	Soft metals.
12	Medium solid sections, ½ to 2 inches thick, and hard steels.
14	Heavy gage structurals and general-purpose cutting.
18	Light sections, 1/16 to ½ inch thick, light structurals, and medium gage sheets and tubing.

22	Very light sections.
24	Very light structurals, and thin gage sheets and tubing.
32	Very thin sheets and tubing.

Exercises (222):
Match the following saw band terms with the correct meaning. Some meanings may be used more than once.

____ 1. Gullet.
____ 2. Gage.
____ 3. Set.
____ 4. Width.
____ 5. Raker.
____ 6. Wave.
____ 7. Temper.
____ 8. Pitch.

a. A particular set pattern.
b. The amount of bend given the teeth.
c. The hardness of the band.
d. The thickness of the band back.
e. The opening between the teeth.
f. The number of teeth per inch.
g. The measurement from the tooth tip to the back of the band.

9. To assure ease in cutting irregular shapes, what part of the saw band should you give your most consideration to?

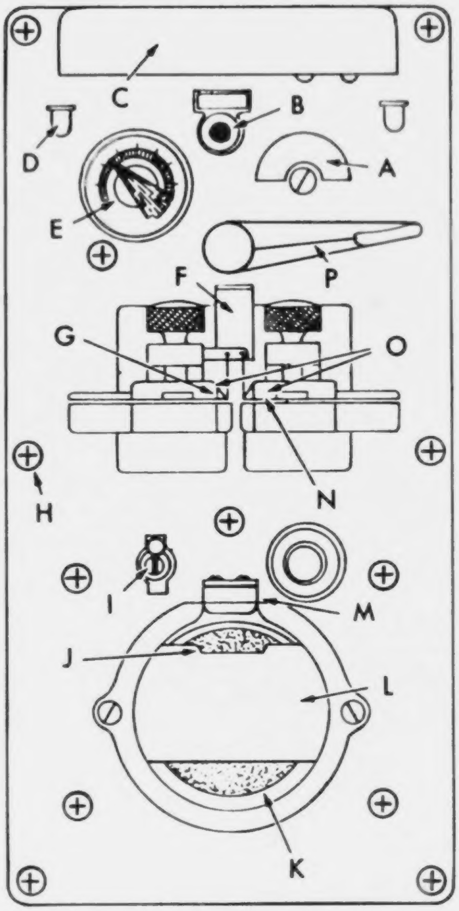
10. If you were told to order a good general-purpose roll of saw band, what pitch should you choose?

223. Describe the process of welding saw bands with the butt welder, and analyze the safety precautions involved.

Butt Welder Operation. Saw bands are usually received in the shop in coiled 100-foot-long lengths. They must be cut to the required length, and then the ends must be welded together to form an endless loop. The butt welder is used for this purpose. Figure 3-10 shows the general arrangement of the panel as viewed by the operator.

To weld a saw band, first cut off the band to the required length and follow this procedure:

- Always cut the band from the back toward the teeth because the teeth and a small area behind them is hardened. Also, align the cut so that it passes through a gullet and not a tooth. Grind the ends of the band square against the side of the grinding wheel. Then insert the ends of the band into the jaws of the butt welder with the teeth pointed toward you, and clamp them in this position by turning the thumb screws. Allow 1/64 to 1/32 between the ends of the band. Set the tension control switch for the width of band and the line voltage regulator for the required welding heat. After placing the flashguard down, depress the operating lever to complete the weld and hold it down until the weld has cooled. BEFORE releasing the operating lever, loosen the stationary jaw thumbscrew, and then release the band from the movable jaws. Move the band forward (toward the operator) to the wide gap



A. Line voltage regulator
B. Etching pencil ground bushing
C. Lamp
D. Oil cups (for grinder)
E. Tension control
F. Flash guard
G. Stationary jaw
H. Mounting screws
I. Lamp and grinder switch
J. Step for squaring saw bands
K. Grinding wheel
L. Grinding wheel guard
M. Weld thickness gage
N. Movable jaw
O. Welder jaws
P. Welding operating lever

Figure 3-10. Butt welder.

annealing position. Reclamp the band just behind the saw teeth, with the newly welded joint centered between the jaws. Now press the annealing switch button until the welded area becomes a dull cherry red.

Turn off the welding panel light so that the correct annealing heat can be observed. Cool the annealed portion gradually by pressing the annealing button several times during the cooling period. After it has cooled enough to be safely handled, remove the band from the jaws and grind the excess weld off both sides of the band. Grind until the welded joint is the same thickness as the band. Use the gage directly above the grinding wheel to check for correct thickness. It is a good idea to re-anneal the band after grinding to relieve stresses set up during grinding.

When you weld saw bands, you should *always* wear safety goggles since the grinding wheel must be used during the welding process. Another safety precaution to keep in mind is that you should not touch the welded portion of the saw band even after it "looks" like it is cool. That area of the band will retain enough heat to cause a painful burn for several minutes after the welding has been completed. Most burns are the result of not paying attention to the welded area during the installation of the band on the drive and idler wheels.

Exercises (223):

1. Describe the way in which a length of saw band should be cut prior to welding.

2. Rearrange the following steps in the order in which they should be accomplished during a band welding process when the band is already locked in the jaws.

____ a. Move band to annealing position and clamp.

____ b. Place flash guard down.

____ c. Depress welding operator lever.

____ d. Set tension control and voltage.

____ e. Release welding operator lever.

____ f. Loosen band from stationary jaw.

____ g. Turn off welding light.

____ h. Loosen band from movable jaw.

____ i. Anneal to dull cherry red.

____ j. Check thickness in gage.

____ k. Re-anneal to relieve stress.

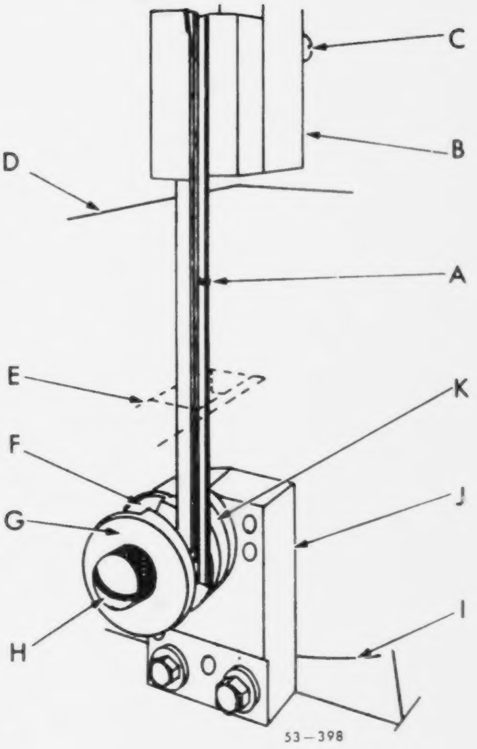
____ l. Remove from clamps and grind smooth.

3. Describe two safety precautions that should be observed during a welding process.

224. Describe the construction and use of file band parts, and select proper file bands for various filing operations.

File Bands. File bands are available in 1/4 inch, 3/8 inch, and 1/2 inch widths and in a flat, half-round, or wide oval shape. The shape of the work determines the shape of the file band to be used. The widest file band that will fit the contour of the work is the best rule in regard to width selection. This cuts down the filing time and also increases the life of the file band.

The band is made up of several parts or *segments* which are riveted at one end (the leading end) to a spring steel band. The trailing end of each segment is free to lift during the time when the band bends over the drive and idler wheels of the contour saw. When the band straightens out, the segments lock together. Figure 3-11 shows the construction of and terminology for file band parts. Note that the *gate segment* (a segment at one end of the band that is specially designed to allow the two band ends to be locked together) has a shoulder rivet and a dowel rivet protruding from beneath it. The shoulder rivet locks into the other file band end and the dowel rivet aligns the two end segments



A. File guide
B. Guidepost
C. File guide screw
D. Table
E. Filler plate
F. Channel for ½" guide
G. File guide support
H. Support screw
I. Trunnion cradle
J. Trunnion keeper block
K. Channel for ¼" guide

Figure 3-16. File guide assembly.

medium pressure will suffice for sawing operations, but on metals that do not dissipate heat rapidly, such as titanium, a heavy feed pressure is best. Be sure that the guide post with the guide inserts is lowered to within ⅛-⅜ inch of the work whenever possible to provide maximum support for the band when the work is being fed into it. Also, you should always use a pusher block instead of your hands to guide and feed work when the power feed attachment is not used. A pusher block can be just about anything that will keep your hands back away from the work and saw band. If you try to feed the work without a pusher block, you run the risk of burning your fingers, since the part will usually become quite hot during the sawing operation. Also, as you near the end of the cut, it is extremely easy to get your fingers in the way as the band breaks through the edge of the material. The use of the power feed attachment will be discussed in a later objective.

The feed pressure for filing depends on how much material is to be removed and the finish required. Since the coarse bands are usually used to remove larger amounts of material, they normally require heavier feed pressure. As the need for better finishes increases, the feed pressure is decreased.

Exercises (228):

1. To properly select the correct speed for a sawing operation, what two things must be considered?

2. How does the recommended speed for sawing titanium and monel differ from that of most other nonferrous metals?

3. What should normally be the maximum fpm for any file band operation?

4. Why should the sawing feed pressure be greater on titanium than on most metals?

5. What governs the amount of feed pressure required for a filing operation?

229. Select proper procedures for straight and contour external sawing.

Straight Sawing. The first thing to do before starting a sawing operation is to put safety glasses or goggles on. Chips produced by the contour saw are very small and they blow around easily, so be sure to protect against them.

For straight sawing you should use the widest available saw band of the proper pitch. This will help keep the band from twisting and will make the cut straighter. Thinner bands are required for contour sawing. This prevents the band from rubbing on the sides of the cut. When a sawed finish is desired, the kerf should just split the layout line on the waste side of the metal. If a filed finish is desired, approximately 1/64 inch should be allowed on the waste side of the layout line. If a corner requires a small radius, the proper size of drill to give this radius should be used. In order to cut a sharp or corner, the corner may be cut to a drilled hole first and then the radius of the hole notched out with the saw. At any rate, the drilling of a hole with a diameter just over the width of the band enables the

BEST COPY AVAILABLE

work to be rotated for the corner without backing the band out of the cut and restarting the cut in a new direction. Square turns may also be made without drilling. This is done by notching a space with the saw. The work can then be rotated while the band is within this notch and a cut can be made in another direction.

In straight sawing you should maintain a constant pressure against the work. Permitting the saw to ride without cutting dulls the saw teeth and can work harden the metal. Use a pusher block to apply pressure to the work to avoid injury to your hands. Saw band breakage during sawing is not common, but if it should occur, stand clear of the machine, press the stop switch, and let the wheels coast to a stop.

Remember, the edge of the saw kerf should split the layout line when a sawed finish is permissible, but be *sure* that the kerf is on the waste or scrap side of the layout line! Position the blower nozzle to blow the chips off the layout line and away from you while you are sawing.

Contour Sawing. Contour sawing is sawing to a layout line of a definite radius or irregular contour. The size of the smallest radius to be cut and the thickness of the material must be considered in selecting the saw band. As the size of the radius decreases, the width of the saw must be decreased to cut the curvature. You should use the widest saw band possible that will allow the contour to be cut. The saw band pitch and set must be suited to the thickness and kind of material to be sawed.

The widest recommended saw band for various radii is given on the job selector dial. As an example, to cut a 1½-inch radius, a ½-inch saw band is recommended, while a ¼-inch saw band is recommended for cutting a ⅝-inch radius. It is usually better to drill a hole if you want to produce radii under ½-inch; but there are saw bands which can cut a 1/16-inch radius or less.

The rule for maintaining constant pressure during the cutting operation applies for contour sawing as well as for straight sawing. It not only prolongs the band life, but also gives more control over the direction of the cut and produces a smoother finish than does a series of intermittent cuts. Also, be sure you use a pusher block.

Exercises (229):

1. In straight sawing on the contour machine, suppose you must make a 90° corner in the saw cut and a ½-inch corner radius is required. Explain how to make this cut with a ½-inch-wide saw band.

2. How can you help prevent injury to your hands when applying feed pressure to the work by hand?

3. A ½-inch-wide saw band is recommended for cutting a 1½-inch radius. Why is this considered to be the widest band suitable for cutting the 1½-inch radius?

4. Explain the advantages of constant feed pressure over intermittent pressure during straight or contour sawing.

230. Describe procedures for straight and contour internal sawing operations.

Internal Sawing. The procedure for internal sawing is essentially the same whether it is straight or contour work; however, most internal sawing can be classified as contour sawing. As in external sawing, you split the layout line if a sawed finish is sufficient, and you leave 1/64 inch for finishing if filing and polishing is required. Internal sawing differs from external sawing mainly in the preparation of the work and saw band. For instance, if you had to cut a square hole in the center of a work piece without cutting through the outer ring, you would need to make a starting place for the saw band.

Therefore the first step in internal sawing is to drill a starting hole in the waste portion of the workpiece tangent to a layout line, and drill any necessary corner holes. The starting hole must be slightly larger in diameter than the width of the saw band. The width of the saw band that you should use depends upon the size of the smallest radius to be sawed. Mount the guide blocks with the proper inserts in them. Now, insert the saw band through the starting hole in the work and weld it together. Make sure that the teeth of the saw band are pointing *down* when it passes through the hole. Place the work on the table, with the saw band in the table groove. Install the band on the wheels. Check to insure that the band is tracking properly. Then insert the filler bar in the table groove. Turn the motor on and set the required speed. Position the air nozzle and perform the sawing.

When you have finished sawing, set the machine for its lowest speed. Place the transmission shift lever in neutral and turn the motor off. Cut the saw band next to the weld and remove the work piece. Finally, cut the welded area off the end of the saw band and reweld the ends together before storing the band. Cutting away the weld in this manner helps keep the number of welds in a band to a minimum.

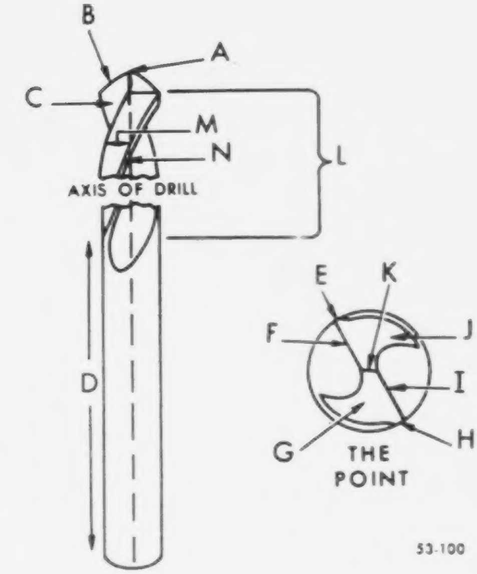
Be careful when you take the saw band out of the machine after finishing the operation. It is easy to forget that part you just cut is hooked to the saw band. If it isn't supported when you pull the band out of the table slot, the part will fall to the bottom of the band, and the resultant jerk on the band can cause severe cuts on your hands. It can also kink the saw band and damage the part.

Exercises (230):

1. What is the first step in preparing for internal sawing operation?

2. Describe the procedure for mounting the saw band for an internal sawing operation.

3. Describe the procedure for removing the finished work and saw band after an internal sawing operation.



A.	Dead center	H.	Margin
B.	Lip of cutting edge	I.	Cutting lip
C.	Flute	J.	Lip clearance
D.	Shank	K.	Dead center
E.	Margin	L.	Body
F.	Cutting lip	M.	Body clearance
G.	Lip clearance	N.	Margin

Figure 4-4. Twist drill.

diameter to 16.0 millimeters diameter. (Extra long metric straight shank bits include sizes to 25.0 millimeters diameter.)

Taper shank drill bits are preferred for drilling medium to large holes because the tang on the shank prevents the bit from spinning in the spindle socket. These drill bits are held in the spindle by friction between the taper on the shank of the bit and the spindle socket. They provide a more positive mounting than do straight shank bits, which can slip in the drill chuck when subjected to heavy cutting pressure. Also, drill chucks with drill bit capacities much larger than ¾ inch diameter are uncommon in the Air Force. Taper shank bits are produced in sizes from ⅛ inch diameter to 2 inches diameter (larger sizes are produced, but are uncommon). Metric bits can also be obtained with tapered shanks.

Reamers. A reamer is a fluted cylindrical tool which is used to size drilled holes to precise diameters. They are also used to produce holes that are round, smooth, and straight. The teeth are unequally spaced around the body of the reamer to prevent chatter. Reamers with spirally cut teeth are more desirable than those with straight-cut teeth because the produce a slightly smoother and more accurate hole. This is because of the extra shearing action that the spiral flutes lend to the teeth. The two most common types of machine reamers are the rose reamer and the standard fluted chucking reamer, as shown in figure 4-5. The rose reamer is mainly a roughing reamer and cuts only with the 45° bevel on the end of the teeth. It has a slight back taper along its length from the cutting end to reduce friction. The amount of metal that may be removed with a rose reamer ranges from 0.005 to 0.015 inch and sometimes to as much as 0.030 inch for roughing purposes.

The fluted chucking reamer, on the other hand, has clearance or relief along the entire length of its side-cutting edges or lands. It is used for finishing holes that are smooth and true to size. Fluted chucking reamers are intended for removing only small amounts of metal in order to accurately size and finish a hole. The amount of metal removed by this type of reamer usually varies from 0.003 to 0.005 inch, with 0.010 inch as a maximum.

Countersinks and center drills. A countersink (which is also referred to as center reamer) is used to enlarge the end of a drilled hole with a large enough chamfer to enable a countersunk (shallow cone shape) bolt or screwhead to lie flush with, or just below, the surface of the work. It can also be used to chamfer a hole prior to tapping threads.

The countersink has teeth milled on its cone-shaped end at standard included angles of 60°, 82°, 90°, or 100°. If you don't have the correct size countersink, you can grind a drill to the required angle to serve as a substitute.

The center drill is really a combination drill and countersink which is used to provide a guide for the

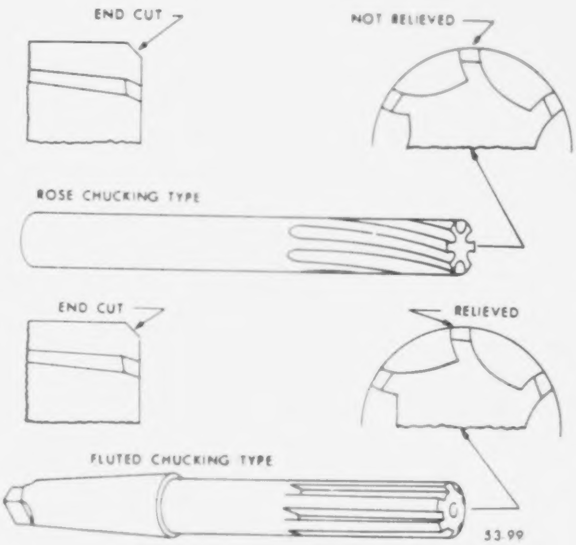


Figure 4-5. Machine reamers.

drill bit. Center drills are produced in a variety of sizes from ⅛ inch (the body diameter) to ½ inch diameter. The center drill you choose should at least be larger in diameter than the length of the dead center (or chisel edge) of the first drill bit that you intend to use.

Counterbores. Counterbores are used to make cylindrical-shaped enlargements at the surface end of a drilled hole usually for the purpose of recessing the head of a screw or bolt. A counterbored hole has a flat bottom. Spot facing (providing a smooth flat surface that is square with the hole) is also accomplished with a counterbore.

The counterbore is an end-cutting tool with three or more straight or spiral teeth relieved at the end to form cutting edges. A pilot in the end of the counterbore centers it in the hole and guides the cutting action. The pilot can be a part of the tool or can be the replaceable type. The body diameter of the counterbore is usually 0.003 to 0.005 inch larger than the standard size, for example, a counterbore for a ½-inch hole may be from 0.503 to 0.505 inch diameter. The pilot is usually from 0.001 to 0.002 inch undersize to prevent it from binding in the hole or enlarging it.

Try a few questions now, and then we will review the drill sharpening procedures you learned in your 3-skill-level studies.

Exercises (240):

1. Name and briefly describe the three main parts of a drill bit.

2. Why are tapered shanks drills recommended for use when drilling larger diameter holes?

3. Describe the main difference in design between the rose reamer and the standard fluted reamer.

4. What are the standard included angles that can be obtained on countersinks?

5. State the uses of a counterboring tool.

241. Explain the procedures for preparing the pedestal grinder and the grinding wheel for sharpening drill bits.

Grinder Preparation. Most of the drill sharpening that you will do in the Air Force will be done on a pedestal grinder. The grinder must be properly prepared if you are to do an efficient job of sharpening a drill bit. A fairly close grained grinding wheel of medium hardness is the best choice for general offhand drill sharpening.

Before grinding a drill, you should dress the abrasive wheel, and, if necessary, true it. The terms "dressing" and "truing" are frequently confused. Dressing is the reconditioning of the abrasive surface of a wheel that has lost some of its cutting ability. This is caused by glazing or loading up (filling the spaces between abrasive particles) or dulling the abrasive particles. Truing is restoring the abrasive wheel to its correct geometrical shape in relation to its axis. Truing is not required as frequently as dressing. The Huntington type dresser, which consists essentially of a number of circular metal cutters mounted on a spindle in a holder, is the most commonly used type of offhand dressing tool. Figure 4-6 shows this tool in use. Here the dulled abrasive grains and any loading of metal or foreign material are being removed so that sharp grains are being presented to the work. Before using the wheel dresser, position the tool rest so that the legs of the dresser may be hooked over it, as shown in figure 4-6. CAUTION: Be sure that the grinder has been turned off before you attempt to loosen the tool rest. After positioning the tool rest, turn the grinder on. Never stand in front of a grinding wheel until after it has been running for several minutes. It may possibly disintegrate when it is first turned on. Also, never operate a grinder without wearing approved goggles or a face shield.

After the wheel has run for several minutes, bring the dresser into contact with the wheel. Then pass the wheel dresser back and forth across the face of the abrasive wheel until it has been properly dressed and trued. Too little pressure will cause excessive sparking and rapid wearing of the dresser cutters and should be avoided. After completing the dressing, turn the grinder off and position the tool rest not more than ¼ inch away from the wheel surface.

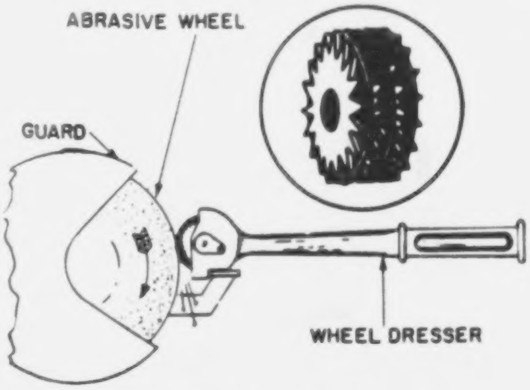


Figure 4-6. Huntington wheel dresser.

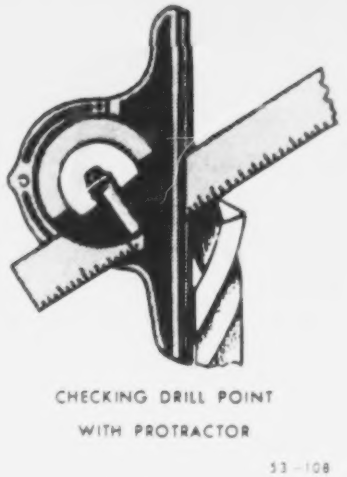


Figure 4-13. Protractor head and blade.

many variations in the way objects can be mounted and secured. Usually the table can be tilted 90° in one direction. There are normally two mounting surfaces; the top surface and an adjacent surface at 90° to the top surface. Each surface is provided with a series of T-slots to facilitate the use of tiedown bolts to secure the vise (as in figure 4-3), clamps, straps, V-blocks, or angle plates.

Before you mount anything on the table, you should check the graduated scale (usually located on both ends of table) to be sure that it is set at the required position. Also, check both the part to be mounted and the table mounting surface for burrs and dirt or grit particles. Burrs should be removed and the parts cleaned to be sure that the setup is true and that neither the part nor the table is damaged.

Exercises (245):

1. When using a vise to secure work in a drill press, what can you do to prevent the drill from cutting into the vise as it breaks through the work?

2. What work holding devices can be used when you cannot hold the work in a vise or V-block?

3. You must drill a series of holes, one of which must be at a 30° angle to the others, in a large work piece and you decide to clamp it to the table of a radial drill press. How can you set it up so that you can drill all the holes without repositioning the work on the table?

4-3. Calculate Speeds and Feeds

Correct feed and speed are necessary because incorrect feed and speed result in poorly drilled holes, wasted time and material, and damage to the cutting tools or equipment. However, no hard-and-fast rules can be given regarding the correct feed and speed to use. In this section we will examine feed and speed requirements, cutting foot speed conversions, and drill press speed changing techniques.

246. Analyze speed and feed requirements for drill press operations, and convert cutting foot speeds to revolutions per minute.

Feed and Speed. To obtain the proper feed and speed for a particular operation, you must take many factors into consideration, such as: (1) the hardness of the metal; (2) the depth of the hole; (3) the size, type, and condition of the cutting tool; (4) the operation being done; (5) the condition of the machine; (6) the work setup; and (7) the type of cutting lubricant being used. The actual feed and speed that you use will be your decision, after all the factors have been considered.

Feed. Feed is the distance the cutting tool advances into the work per spindle revolution. When you are using hand feed during a drilling operation, you must apply enough pressure without forcing the drill bit. You should *drill* the hole, not "punch" it out. Applying too much pressure chips the cutting edges and may even split the drill bit along the web. During a drilling operation, you should reduce the pressure as the drill bit begins to emerge in order to prevent the work from "climbing up" the drill bit. This is especially true when you are drilling very thin pieces. Figure 4-15 gives the recommended feeds when power feed is used.

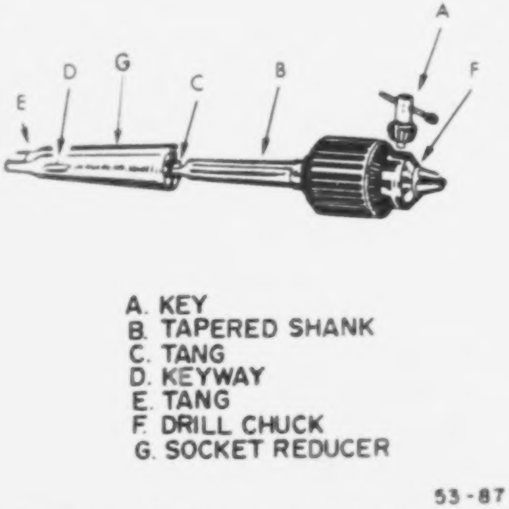


Figure 4-14. Socket reducer and drill chuck.

The lower values in the table of feeds should be used when drilling harder materials and the higher values should be used when drilling softer materials.

Speed. The speed of a drill press refers to the number of revolutions per minute (RPM) of the spindle. It is necessary that you know how to determine the

TABLE OF FEEDS	
DRILL SIZE (INCHES)	FEED (PER REV)
1/8 AND LESS	.001 TO .002
1/8 TO 1/4	.002 TO .004
1/4 TO 1/2	.004 TO .007
1/2 TO 1	.007 TO .015
1 AND LARGER	.015 TO .025

53—133

Figure 4-15. Drill feeds.

speed to use for drilling and then how to set the machine to obtain the desired RPM.

As a drill bit rotates, a point located on its outer surface (periphery) travels a certain distance in 1 minute of time. The exact distance traveled depends upon the distance around the drill (circumference) and the speed of its rotation (RPM). When this distance is changed from inches to feet, it is called the surface foot speed (SFS). It has been determined through experience and experiment that various metals machine best when a specific SFS is maintained. This desired SFS is known as the cutting foot speed (CFS). Figure 4-16 gives the CFS for various materials. The lower CFS is generally used for drilling and rough machining operations. The higher CFS is ordinarily used for finishing operations.

Since a change of drill diameter results in a change of circumference, the RPM must be changed in order to obtain a desired CFS. For example, a drill bit ½-inch in diameter has a circumference one-half of that of a drill bit 1 inch in diameter and must revolve twice as fast as the latter to obtain the same CFS. You can see that you must take the diameter of the drill into consideration when you are calculating the spindle RPM to use. The most practical formula for determining spindle speed is:

$$\text{RPM} = \frac{4 \times \text{CFS}}{\text{drill diameter}}$$

For example, if you were to drill a ½-inch hole in low carbon steel, the formula would be as follows:

MATERIAL	CUTTING FOOT SPEED
LOW CARBON STEEL	80 TO 110
MEDIUM CARBON STEEL	60 TO 80
HIGH-CARBON TOOL STEEL	50 TO 60
STEEL FORGINGS	50 TO 60
STAINLESS STEEL	30 TO 40
SOFT CAST IRON	100 TO 150
HARD DRILLED CAST IRON	70 TO 100
MALLEABLE IRON	80 TO 90
ORDINARY BRASS AND BRONZE	200 TO 300
HIGH-TENSILE BRONZE	70 TO 150
MONEL	40 TO 150
ALUMINUM AND ITS ALLOYS	200 TO 300
MAGNESIUM AND ITS ALLOYS	250 TO 400
BAKELITE	100 TO 150
WOOD	300 TO 400

NOTE: CARBON STEEL DRILLS SHOULD BE RUN AT SPEEDS OF FROM 40 TO 50 PERCENT SLOWER THAN THOSE GIVEN ABOVE.

53—134

Figure 4-16. Cutting foot speeds.

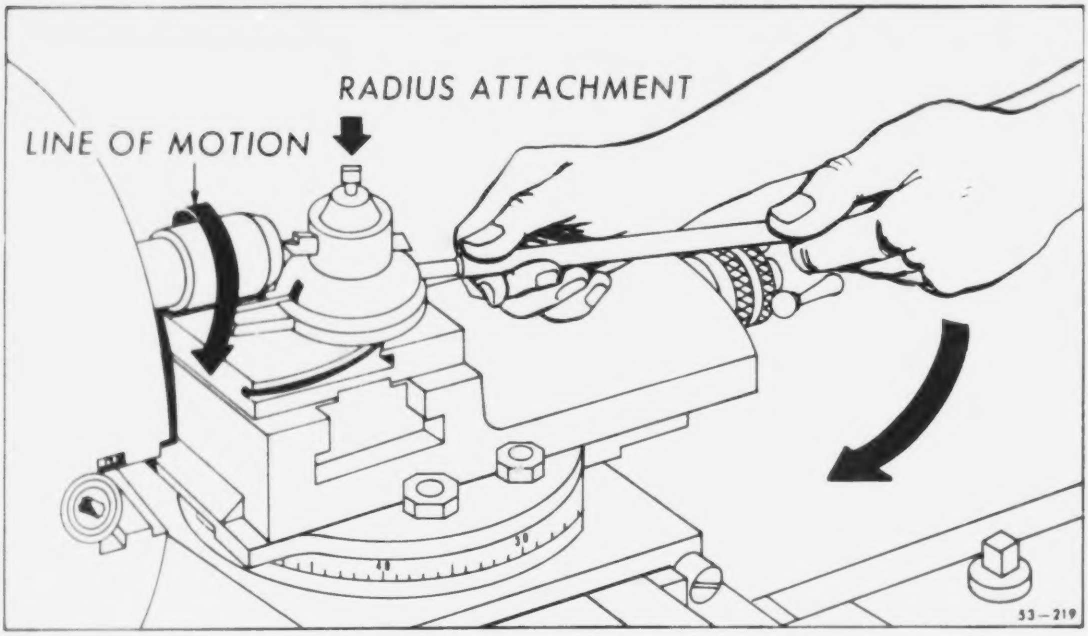


Figure 5-15. Radius turning attachment.

4. Explain the general characteristics of a self-releasing taper.

5. Explain the method of checking a taper with a micrometer.

256. Describe the calculations and the procedures for machining internal and external tapers with the compound rest, including filing and polishing practices.

Taper Turning with the Compound Rest. Both external and internal tapers can be turned with the compound rest. You use the compound rest primarily to machine short, steep tapers, since the length of the taper that can be cut is restricted to the distance the compound can be moved. Position the compound rest at an angle measured from the centerline of the work, figure 5-19,A, or from a line perpendicular to the centerline of the work, figure 5-19,B. For example, the 40° angle in figure 5-19,B, is measured from a line perpendicular to the centerline of the work. In order to machine this angle you must first position the compound rest perpendicular to the centerline, and then move it the required 40°. The graduations on the base of the compound rest swivel represent 1°. You obtain fractions of a degree by estimating the fractional spacing between divisions.

The amount of taper is often designated as taper per inch (TPI) or taper per foot (TPF). Frequently no actual designation of the amount of taper is given at all. The large diameter (LD), the small diameter (SD), and the length of the taper (L of T) are specified, and you must find the TPI before you can set the compound rest properly. To determine the angle at which the compound rest should be set, use the following

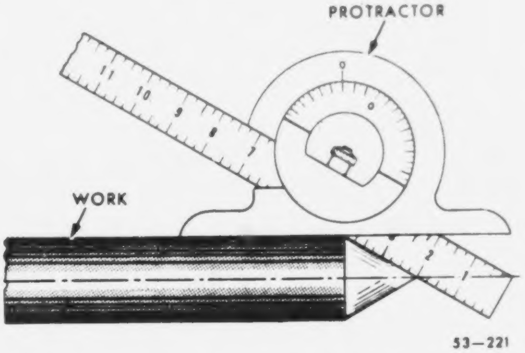


Figure 5-16. Checking taper with a protractor head.

formulas which apply both to external and internal tapers:

$$\text{TPI} = \frac{\text{LD - SD}}{\text{L of T}}$$

Tangent of the angle $(\tan\angle) = \frac{\text{TPI}}{2}$

Let us apply the formulas above, first, when the TPI is given, and, second, when only the dimensions of a

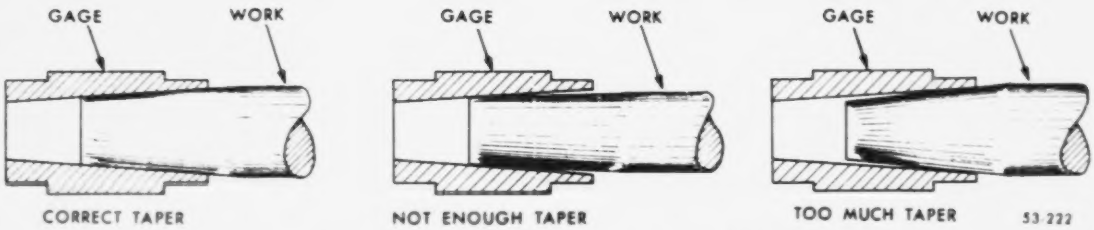


Figure 5-17. Checking taper with a tapered ring gage.

taper are given: If the TPI were given as 0.800 inch, you would calculate the angle as follows:

$$\text{Tan} = \frac{\text{TPI}}{2} = \frac{0.800}{2} = 0.400$$

Once the tangent of the angle has been calculated, as in our example, you must then convert that to the corresponding angle. It would be possible to calculate the angle; however, it is more convenient to obtain the information from a table of trigonometric functions (often called *trig tables*). Trig tables can be found in machinist's publications such as the *Machinery's Handbook* and in trigonometry handbooks. A portion of a trig table is shown in figure 5-19a. Refer to that figure as we discuss the procedure for finding the actual angle that corresponds to the tangent. You must first find the number nearest to 0.400 in the tan column of the table. You will find that 0.39997 is the nearest number. Since this number is listed in the column labeled "Tan" at the top of the table, the degree of the angle will be found at the top left corner of the table; hence, 21°. Each degree is broken down into minutes in the "M" column. Using the column on the left side of the table, you will find that 0.39997 corresponds to 48 minutes (48′). Therefore, the angle that we are looking for is 21°48′. So, to machine a taper with a TPI of 0.800 inch using the compound rest, you would set the compound rest parallel with the bed ways and then swivel it 21¾°. If TPF had been given instead of TPI, it would have been necessary to convert it into TPI by dividing the TPF by 12 prior to calculating the tangent. For example:

$$\text{TPF} = 9.6 \text{ inches; TPI} = \frac{9.6}{12} = 0.800 \text{ inch}$$

If the dimensions of a taper instead of the angle are given, the calculations would be as follows:

Given:

LD = 3.00 inches
SD = 0.500 inch
L of T = 0.500 inch

$$\text{TPI} = \frac{\text{LD - SD}}{\text{L of T}} = \frac{3.00 - 0.500}{0.500} = 5.000$$

$$\text{Tan} = \frac{\text{TPI}}{2} = \frac{5.000}{2} = 2.500$$

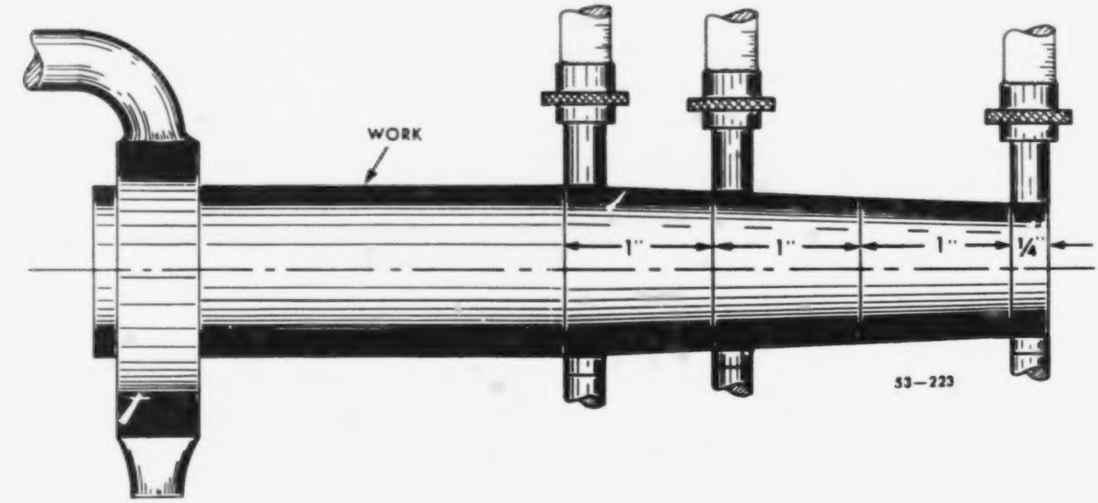


Figure 5-18. Measuring taper per inch with a micrometer.

21° **Natural Trigonometric Functions** **158°**

M	Sine	Cosine	Tan.	Cotan.	Secant	Cosec.	Vrs. Sin.	Vrs. Cos.	M
0	0.35837	0.93358	0.38386	2.6051	1.0711	2.7904	0.06642	0.64163	60
1	.35864	.93348	.38420	.6028	.0713	.7883	.06652	.64136	59
2	.35891	.93337	.38453	.6006	.0714	.7862	.06663	.64109	58
3	.35918	.93327	.38486	.5983	.0715	.7841	.06673	.64082	57
4	.35945	.93316	.38520	.5960	.0716	.7820	.06684	.64055	56
5	0.35972	0.93306	0.38553	2.5938	1.0717	2.7799	0.06694	0.64027	55
6	.36000	.93295	.38587	.5916	.0719	.7778	.06705	.64000	54
7	.36027	.93285	.38620	.5893	.0720	.7757	.06715	.63973	53
8	.36054	.93274	.38654	.5871	.0721	.7736	.06726	.63946	52
9	.36081	.93264	.38687	.5848	.0722	.7715	.06736	63919	51
10	0.36108	0.93253	0.38720	2.5826	1.0723	2.7694	0.06747	0.63892	50
11	.36135	.93243	.38754	.5804	.0725	.7674	.06757	.63865	49
12	.36162	.93232	.38787	.5781	.0726	.7653	.06768	.63837	48
13	.36189	.93222	.38821	.5759	.0727	.7632	.06778	.63810	47
14	.36217	.93211	.38854	.5737	.0728	.7611	.06789	.63783	46
15	0.36244	0.93201	0.38888	2.5715	1.0729	2.7591	0.06799	0.63756	45
16	.36271	.93190	.38921	.5693	.0731	.7570	.06810	.63729	44
17	.36298	.93180	.38955	.5671	.0732	.7550	.06820	.63702	43
18	.36325	.93169	.38988	.5649	.0733	.7529	.06831	.63675	42
19	.36352	.93158	.39022	.5627	.0734	.7509	.06841	.63648	41
20	0.36379	0.93148	0.39055	2.5605	1.0736	2.7488	0.06852	0.63621	40
21	.36406	.93137	.39089	.5583	.0737	.7468	.06863	.63593	39
22	.36433	.93127	.39122	.5561	.0738	.7447	.06873	.63566	38
23	.36460	.93116	.39156	.5539	.0739	.7427	.06884	.63539	37
24	.36488	.93105	.39189	.5517	.0740	.7406	.06894	.63512	36
25	0.36515	0.93095	0.39223	2.5495	1.0742	2.7386	0.06905	0.63485	35
26	.36542	.93084	.39257	.5473	.0743	.7366	.06916	.63458	34
27	.36569	.93074	.39290	.5451	.0744	.7346	.06926	.63431	33
28	.36596	.93063	.39324	.5430	.0745	.7325	.06937	.63404	32
29	.36623	.93052	.39357	.5408	.0747	.7305	.06947	.63377	31
30	0.36650	0.93042	0.39391	2.5386	1.0748	2.7285	0.06958	0.63350	30
31	.36677	.93031	.39425	.5365	.0749	.7265	.06969	.63323	29
32	.36704	.93020	.39458	.5343	.0750	.7245	06979	.63296	28
33	.36731	.93010	.39492	.5322	.0751	.7225	.06990	.63269	27
34	.36758	.92999	.39525	.5300	.0753	.7205	.07001	.63242	26
35	0.36785	0.92988	0.39559	2.5278	1.0754	2.7185	0.07012	0.63214	25
36	.36812	.92978	.39593	.5257	.0755	.7165	.07022	.63187	24
37	.36839	.92967	.39626	.5236	.0756	.7145	.07033	.63160	23
38	.36866	.92956	.39660	.5214	.0758	.7125	.07044	.63133	22
39	.36893	.92945	.39694	.5193	.0759	.7105	.07054	.63106	21
40	0.36921	0.92935	0.39727	2.5171	1.0760	2.7085	0.07065	0.63079	20
41	.36948	.92924	.39761	.5150	.0761	.7065	.07076	.63052	19
42	.36975	.92913	.39795	.5129	.0763	.7045	.07087	.63025	18
43	.37002	.92902	.39828	.5108	.0764	.7026	.07097	.62998	17
44	.37029	.92892	.39862	.5086	.0765	.7006	.07108	.62971	16
45	0.37056	0.92881	0.39896	2.5065	1.0766	2.6986	0.07119	0.62944	15
46	.37083	.92870	.39930	.5044	.0768	.6967	.07130	.62917	14
47	.37110	.92859	.39963	.5023	.0769	.6947	.07141	.62890	13
48	.37137	.92848	.39997	.5002	.0770	.6927	.07151	.62863	12
49	.37164	.92838	.40031	.4981	.0771	.6908	.07162	.62836	11
50	0.37191	0.92827	0.40065	2.4960	1.0773	2.6888	0.07173	0.62809	10
51	.37218	.92816	.40098	.4939	.0774	.6869	.07184	.62782	9
52	.37245	.92805	.40132	.4918	.0775	.6849	.07195	.62755	8
53	.37272	.92794	.40166	.4897	.0776	.6830	.07205	.62728	7
54	.37299	.92784	.40200	.4876	.0778	.6810	.07216	.62701	6
55	0.37326	0.92773	0.40233	2.4855	1.0779	2.6791	0.07227	0.62674	5
56	.37353	.92762	.40267	.4834	.0780	.6772	.07238	.62647	4
57	.37380	.92751	.40301	.4813	.0781	.6752	.07249	.62620	3
58	.37407	.92740	.40335	.4792	.0783	.6733	.07260	.62593	2
59	.37434	.92729	.40369	.4772	.0784	.6714	.07271	.62566	1
60	0.37461	0.92718	0.40403	2.4751	1.0785	2.6695	0.07282	0.62539	0
M	Cosine	Sine	Cotan.	Tan.	Cosec.	Secant	Vrs. Cos.	Vrs. Sin.	M

111° **68°**

Figure 5-19a. Trig table.

Refer again to figure 5-19a to obtain the angle. To find the nearest number to 2.500 in the tan column, you must enter the table from the bottom. Going up the column, you will find the nearest number to be 2.5002. Since you entered the table from the bottom this time, your readings will be obtained from the bottom left corner and left side of the table. Therefore, the angle is 68° 12', so the compound rest should be swiveled 68⅕° from a position parallel to the bed ways.

When you machine a taper with a compound rest (or any other method), be sure to set the tool bit at center height. This applies to both external and internal tapers. If the tool bit is not at center height, the taper will not be accurate even if the compound rest is set up for the correct angle.

Internal taper boring usually requires the tool bit to be partially obscured while it is in the tapered hole. Be careful to allow room inside the hole to back the tool bit off the surface to bring it back out of the hole. If there isn't enough room and the hole cannot be drilled any larger (because the small taper diameter is close to the hole diameter), then it may be necessary to grind part of the back side of the tool away. If the tool is allowed to rub when you back it off, it will mar the taper surface and possibly break the tool bit.

Most of the tapers that you turn with the compound rest will have to be filed and/or polished. This is because it is hard to attain a smooth finish with this method since the

BEST COPY AVAILABLE

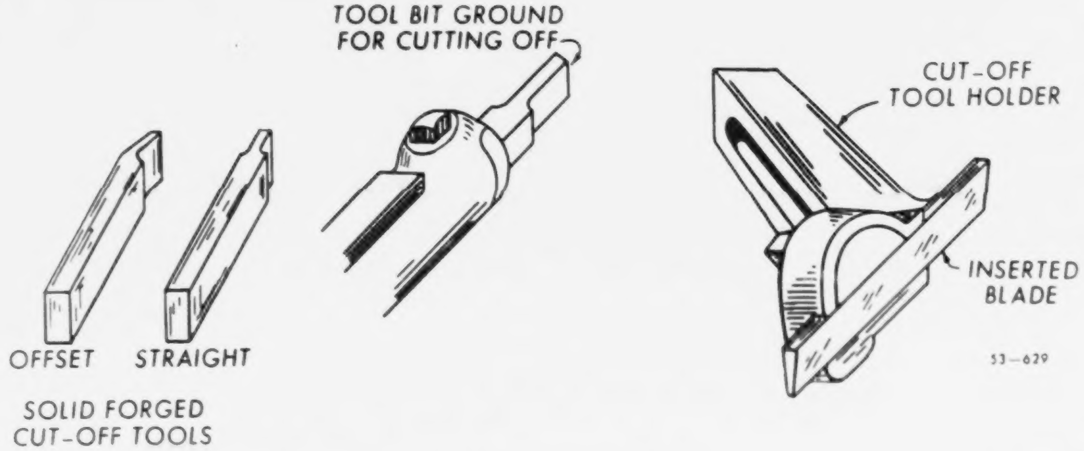


Figure 5-34. Types of parting tools.

to shape from tool bits. Examples for these three types are shown in figure 5-34.

The solid, forged-type parting tool is forged from either carbon steel or high-speed steel and is ground to meet the requirements of the job at hand. It may be either straight or offset. This tool is being rapidly replaced by the inserted cutter blade-type parting tool.

The inserted blade-type parting tools are made in a variety of sizes and are held in special toolholders. The toolholders are available in straight and offset types, a shown in figure 5-35. You can sharpen the blades repeatedly and replace them when they are too short to hold safely in the toolholder. Some blades are manufactured with the necessary flank and side relief angles ground in them; only the end relief is ground when you sharpen them. Flank relief is the clearance ground on both sides of the parting tool behind the cutting edge. Flank relief helps to prevent the sides of the parting tool from contacting the sides of the groove that is formed during parting.

Parting tools ground from tool bits, as shown in figure 5-36, are used mostly on small work. The cutting edge may be ground straight or offset, as shown in figure 5-36, A and B. The top of the tool is ground down, as shown in figure 5-36,C, to eliminate the excessive back rake created by the toolholder.

Parting tool geometry. The general shape of parting tools is the same for all three types. They are ground so that the cutting edge is the widest part of the tool. Grind both sides of the tool with 1° to 2° of flank relief (fig. 5-37,B). Back rake is usually eliminated for parting soft metal, such as brass, and the end relief should be approximately 15° (fig. 5-37,C). For steel and harder metals a back rake of about 5° gives free cutting action and helps to curl the chip. The end relief should be approximately 10° (fig. 5-37,D). In order for the tool to have maximum strength, the length of the cutting portion of the blade should be only slightly greater than half the diameter of the work to be parted.

Exercises (260):

1. List and briefly describe the three common types of parting tools.

2. Explain flank relief and side clearance as it pertains to parting tools and state the recommended angles for each.

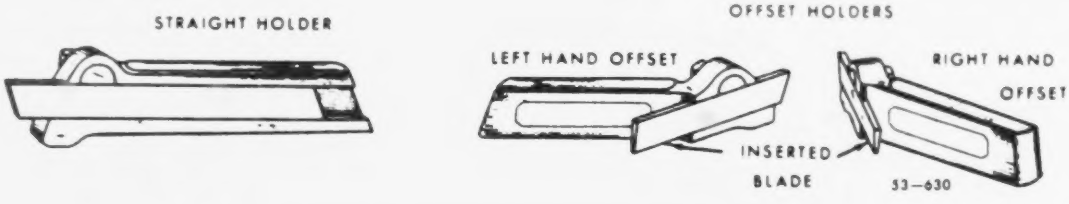


Figure 5-35. Inserted blade parting tools and holders.

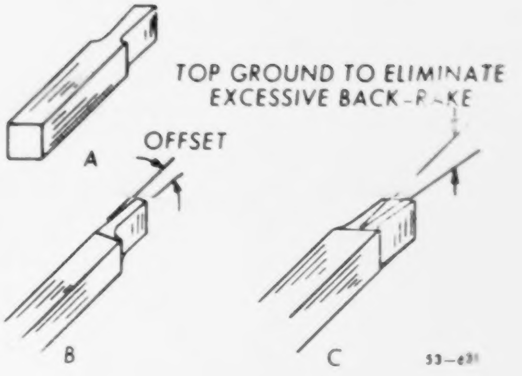


Figure 5-36. Parting tool ground from tool bits

261. Explain the lathe parting operation, including setup and safety precautions.

Parting Tool Setup and Operation. Work to be parted should be held in a chuck, preferably the four-jaw type, with the point at which the parting is to occur as close as possible to the chuck jaws. Always make the parting cut at a right angle to the centerline of the work and feed the tool into the revolving work with the cross-slide until the tool completely severs the work. The tool may be fed by hand; however, the cutting action of the tool is usually enhanced when the power feed on the cross slide is used. This is because the power feed produces a smooth, even tool movement which helps to prevent chattering or gouging. As a general rule, a feed of about 0.002 inch per revolution is sufficient; however, the actual feed you will use will depend on the type and hardness of the material to be parted as well as the type of tool and work setup being used.

Cutting speeds for parting are usually somewhat slower than turning speeds. You should use a feed that will keep a thin chip coming continuously from the work. If chatter occurs, decrease the speed and increase the feed. If the tool tends to gouge or dig in, decrease the feed. If decreasing the feed does not stop the gouging, you should decrease the amount of back rake on the tool bit. The parting tool should be at center height. It must be square to the work axis to prevent the tool from binding in the cut.

On large diameter jobs where there is danger of the tool binding in the groove, you should use the step-parting method. In step parting you feed the tool into the work a short distance. Then you withdraw the tool from the groove, move the carriage slightly to one side, and feed the tool in again. This leaves only one side of the tool in contact with the groove and prevents binding. Take alternate cuts until the work is cut off.

The length of the portion to be cut off may be measured by placing the edge of a steel rule against the side of the work and the end of the rule against the side of the parting tool. Move the carriage until the desired length is obtained. You may also align the parting tool to a layout line scribed on the work.

When greater accuracy is required, the micrometer carriage stop may be used. You must remember, however, to add the width of the parting tool cutting edge to the distance that the carriage stop is moved. For example, if you were parting 0.250-inch spacers with a 0.125-inch wide parting tool, you would adjust the carriage stop 0.250 inch plus 0.125 inch, or a total of 0.375 inch for each spacer to be cut.

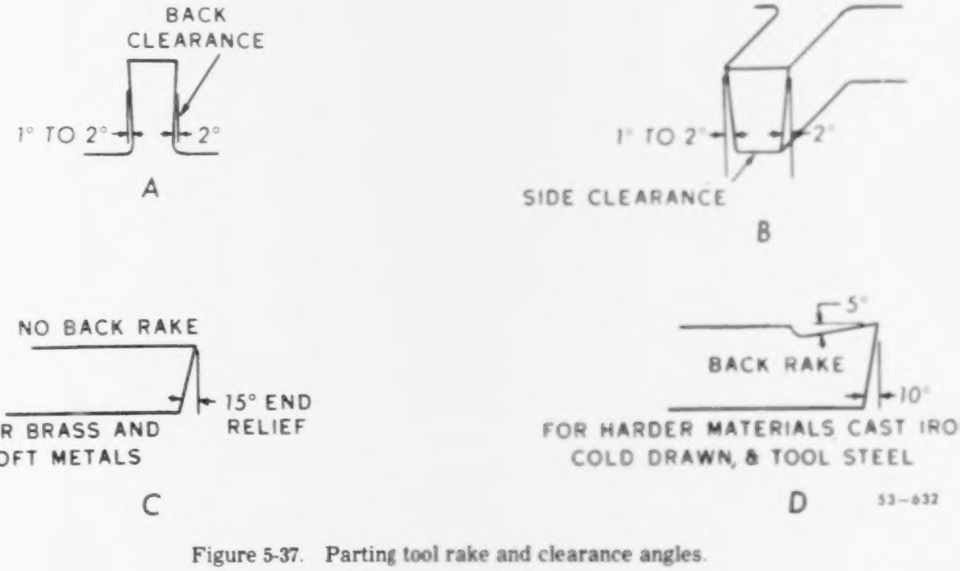


Figure 5-37. Parting tool rake and clearance angles.

Another very accurate method is to use a depth micrometer and measure from the face of the work to the edge of the parting tool. In this case, the width of the parting tool cutting edge does not need to be considered, which usually lessens the chance of error. NOTE: Always lock the carriage in position to prevent it from moving while you are taking the parting cut. CAUTION: Never attempt to catch the piece that has been parted off. It will probably be hot and it will have dangerous burrs and sharp edges on it. Now it's time for some more questions and then we will begin a section on threading operations on the lathe.

Exercises (261):

1. Explain the parting tool setup.

2. What is the probable cause of the tool gouging into the work during a parting operation?

3. Why shouldn't you try to catch a piece that has been parted off?

5-4. Threading Operations

Cutting threads on the lathe will be a big part of your work as a machinist. There are many types of threads and many types of thread cutting operations any one of which you may be called on to machine or perform. In this section we will examine thread types and terminology and threading procedures for left-hand, multiple lead, pipe, acme, square, and metric threads plus tap and die operations on the lathe.

262. Interpret thread terminology and designations.

Threading Terms. To be able to understand threads and threading operations, you must know the meaning of certain terms. Figure 5-38 will help you to understand the following definitions.

- Thread. A thread is the ridge or projection remaining after a uniform, helical groove is cut on the outside or inside of a shaft or hole.
- Threads per inch. Threads per inch is the number of threads per inch measured parallel to the thread axis. It is used in conjunction with the outside diameter to designate the size of the thread. For example, ¾-10 indicates 10 threads per inch on a piece of stock ¾ inch in diameter.
- Thread angle. The thread angle is the angle formed by the intersection of the two sides of the thread groove.
- Helix angle. The helix or lead angle is the angle formed by the inclination of the thread and a plane perpendicular to the thread axis.
- Major diameter. The major diameter is the largest diameter of an external or internal thread.
- Pitch diameter. The pitch diameter is the diameter of an imaginary cylinder that is concentric with the thread axis and whose periphery passes through the thread profile at the point where the width of the thread and the thread groove are equal. The pitch diameter is the diameter which is measured when the thread is machined to size. A change in pitch diameter changes the fit between the thread being machined and the mating thread.
- Nominal size. The nominal size is the size which is used for identification. For example, the nominal size of a ½-20 thread is ½ inch, but its actual size is slightly smaller to provide clearance.
- Actual size. The actual size is the measured size.
- Basic size. The basic size is the theoretical size. The basic size is changed to provide the desired clearance or fit.
- Pitch. Pitch is the distance from a point on a thread to a corresponding point on the next thread measured parallel to the thread axis.
- Lead. Lead is the lateral distance a thread moves per revolution. On a single-lead thread, the lead and the pitch are identical; on a double-lead thread, the lead is twice the pitch; on a triple-lead thread, the lead is three times the pitch; etc.
- Crest. The crest of a thread is the top surface that joins the two sides of the thread.
- Root. The root of a thread is the bottom surface that joins the two sides adjacent threads.
- Truncation. Truncation is the perpendicular distance from the crest of a thread or the root of a thread and the point of intersection that would be created if the sides of the thread were extended to form a sharp "V."
- Crest clearance. Crest clearance is the perpendicular distance between the crest of a thread and the root of a mating thread when it is engaged.
- Thread depth. Thread depth is the perpendicular distance between the crest and root of a thread.
- Width of a basic crest or a basic root. The width of a basic crest or a basic root of an American Standard Unified thread is one-eighth of the pitch.

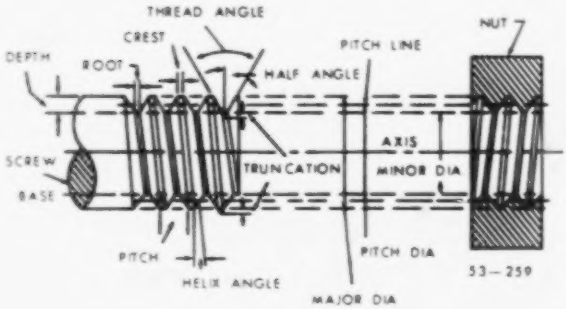


Figure 5-38. Thread parts.

Thread Designation. A thread is designated according to the nominal size, the number of threads per inch, the series symbol, and the class symbol, in that order. For example, the designation ¼-20 UNC-3A is explained as follows:

¼ = nominal thread diameter
20 = number of threads per inch
UNC = series (Unified coarse)
3 = class
A = external thread

Unless the designation LH (left hand) follows the class designation, the thread is assumed to be a right-hand thread. An example of the designation for a left-hand thread is: ¼-20 UNC-3A-LH. The symbols used to identify the thread series are these:

UNC-Unified coarse
UNF-Unified fine
UNEF-Unified extra fine
UNS-Unified special

Constant pitch series are identified by the number of threads per inch of the series, followed by the Unified symbol (UN), such as 8UN or 32UN. The same symbols are used to identify the old National Thread System, except that the letter U is omitted. For example: ¼-20NC-2.

The class symbol designates the tolerance grouping to apply to a given thread. Each size of thread has three classes of fit, which are identified as class 1, 2, or 3. In addition to the numerical designation, the letter A indicates an external thread class and the letter B indicates an internal thread class. The tolerances for class 1 threads are greater than those for class 2, and the tolerances for class 2 threads are greater than those for class 3 threads. Any desired fit can be obtained by using an external thread of one class with an internal thread of another class, such as a 2A bolt and a 3B nut

Metric thread designations differ significantly from those of the Unified series. We will examine two examples of ISO (*International Organization* for *Standardization*) metric thread designations: M10 × 1.5 - 7H and M10 × 1.5 - 8g. You will notice that the only difference in the two examples is in the last two figures. These figures designate the class of fit of the thread and also specify whether the thread is internal or external. Internal ISO metric threads are designated by capital letters in the class designation and small letters for external threads. Therefore, our first example is internal thread and the second is an external thread. Both are right-hand threads. In fact, all ISO metric threads are considered to be right hand unless otherwise specified.

There are three classes of fit for ISO metric threads: *close, medium,* and *free.* For internal threads, the designations are 5H (close), 6H (medium), and 7H (free). For external threads, the designations are 4g (close), 6g (medium), and 8g (free). The medium class (6H and 6g) is the class of fit that is commonly used for most general engineering purposes. In our example, the internal thread is a medium class fit, and the external thread is a free class fit. In both examples, the "M10 × 1.5" is broken down as follows: the "M" is the thread system symbol for ISO metric threads, the "10" is the nominal size of the thread in millimeters (mm), and the "1.5" is the thread pitch in mm.

Complete listings of Unified and ISO metric threads and the dimensions of the threads for each class can be found in machinists' publications, such as the *Machinery's Handbook.*

Exercises (262):

1. What is the helix angle of a thread?

2. What is the difference between pitch and the pitch diameter?

3. Interpret the meaning ¼-28UNF-3B.

4. In the thread designation M9 × 1.25-5H, interpret the meaning of "5H."

263. Describe the various methods of thread measurement, including calculations for using the three-wire method.

Thread Measurement. Thread measurement is necessary to insure that the thread and its mating part will fit properly. It is important that you know the various measuring methods and the calculations which are used to determine the dimensions of threads.

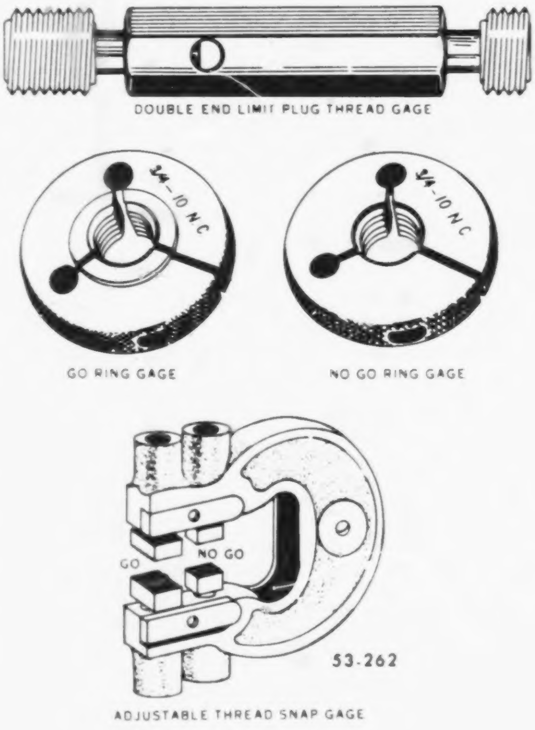

DOUBLE END LIMIT PLUG THREAD GAGE
¾-10 NC
¾-10 NC
GO RING GAGE
NO GO RING GAGE
GO
NO GO
53-262
ADJUSTABLE THREAD SNAP GAGE

Figure 5-39. Thread gages.

Several methods can be used to check threads. The one which you will use will depend upon the accuracy required for the particular thread which you are machining.

Mating part. The use of a mating part is a common practice when average accuracy is required. The thread is simply machined until the mating part will assemble. A snug fit is usually desired, with very little play, if any, between the parts.

Thread gages. Go and no-go gages, such as those shown in figure 5-39, are often used to check threaded parts. The thread should fit the go portion of the gage; but should not fit the no-go portion. The threaded plug gage is one of the most exact means of checking internal threads.

Thread calipers. Thread calipers are similar to common calipers, except that the legs are ground to the shape of a thread. They are used to measure from a finished thread to the thread being machined and are fairly accurate.

Thread micrometers. Thread micrometers are used to measure the pitch diameter of threads. They are graduated and are read in the same manner as are ordinary micrometers. However, the anvil and spindle are ground to the shape of a thread, as shown in figure 5-40. Thread micrometers come in the same size ranges as ordinary micrometers: 0 to 1 inch, 1 to 2 inches, etc. In addition, they are available in various pitch ranges. The number of threads per inch must be within the pitch range of the thread micrometer. The

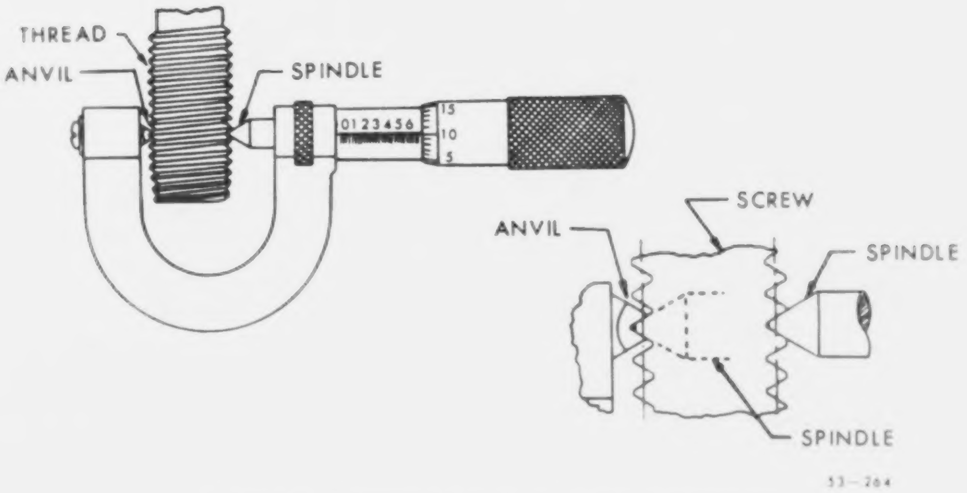


Figure 5-40. Measuring threads with a thread micrometer.

thread micrometer method is one of the most accurate methods for measuring pitch diameter.

Micrometer and wires. The pitch diameter of a thread can also be accurately measured by an ordinary micrometer and three wires, as shown in figure 5-41.

The wire size which should be used to measure the pitch diameter depends upon the number of threads per inch. The most accurate results are obtained when you use the "best wire size." The best size is not always available, but you will obtain satisfactory results if you use wire diameters within a given range. Use a wire size as close as possible to the best wire size. You can use these formulas:

$$\text{Best wire size} = \frac{0.57735}{\text{number of threads per inch}}$$

$$\text{Smallest permissible size} = \frac{0.56}{\text{number of threads per inch}}$$

$$\text{Largest permissible size} = \frac{0.90}{\text{number of threads per inch}}$$

For example, the diameter of the best wire for measuring a thread having 10 threads per inch is 0.0577 inch, but any size between 0.056 inch and 0.090 inch could be used.

NOTE: The wires should be fairly hard and uniform in diameter. All three wires must be the same size. The shanks of drill bits can be used as substitutes for the wires.

The three-wire method does not measure the pitch diameter directly; it does this indirectly. A measurement taken over wires of a given diameter will be a specific dimension when the pitch diameter is correct. Use the following formulas to determine what the measurement should be.

$$\text{Measurement} = \text{major diameter of thread} - \frac{1.5155}{\text{number of threads per inch}} + (3\text{x wire diameter})$$

or

$$M = MD - \frac{1.5155}{\text{no. threads}} + (3W)$$

NOTE: The actual size of the wires should be used in the formula, not the calculated size. *Example:* What should the measurement over the wires be for a ¾-10-UNC thread if the diameter of the wire is 0.070 inch?

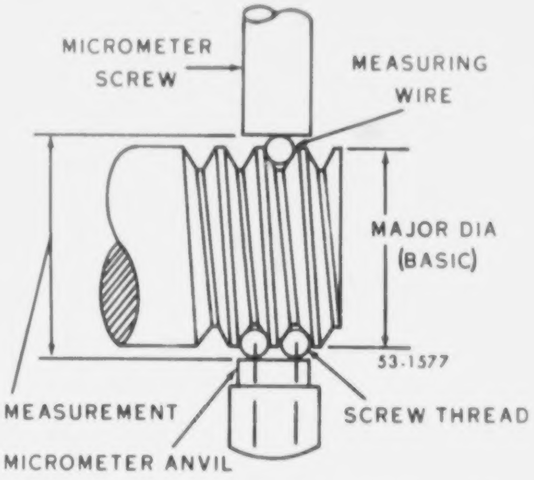


Figure 5-41. Measuring threads using three wires.

$$M = 0.750 - \frac{(1.5155)}{10} + (3 \times 0.070)$$
$$M = 0.750 - (0.15155) + (0.210)$$
$$M = 0.59845 + 0.210$$
$$M = 0.80845 \text{ inch}$$

Exercises (263):

1. Describe the thread gage and thread micrometer method of measuring threads.

2. Calculate the measurement over the wires for measuring a ¼-20-UNC thread when the wires measure 0.029 inch.

264. Explain the purpose of left-hand threads and the procedures for machining them.

Left-Hand Threads. Threads may be either right hand or left hand. A thread is a right-hand thread if it is advanced by turning it in a clockwise direction. A thread is a left-hand thread if it winds in a counterclockwise and receding direction when it is viewed axially. Most threads are right hand; therefore a thread is considered to be right hand unless the symbol LH is used on drawings, taps, dies, etc. Left-hand threads are used when the direction of motion required is opposite to that obtained with a right-hand thread. Examples are crossfeed screws and one end of turnbuckles; or a situation in which a slippage between a part and a nut would tend to loosen a right-hand nut, such as on one end of a vehicle axle.

Left-hand threads are cut in approximately the same manner as right-hand threads except that the carriage moves toward the tailstock instead of away from it. Also, you swivel the compound rest to the left instead of the right to cut external left-hand threads, and to the right instead of the left to cut internal left-hand threads. Figure 5-42 shows the setup for machining external left-hand Unified threads. You grind the tools for left-hand threads with the relief and rake angles reversed from those on right-hand threading tools.

An undercut, or groove, is usually provided as a starting point for the left-hand threading tool. The undercut should be no narrower than the thread pitch and of a depth equal to, or slightly greater than, a single thread depth. The side nearest the thread should be chamfered.

Exercises (264):

1. Explain the purpose of left-hand threads.

2. How are tool bits for left-hand threads different from those for right-hand threads?

3. Explain how the work should be prepared prior to making the first cut for an external left-hand thread.

265. Analyze the characteristics of multiple lead threads, and explain the various procedures for machining them.

Multiple Threads. A multiple thread, as shown in figure 5-43, is a combination of two or more threads, parallel to each other, progressing around the surface into which they are cut. If a single thread is thought of as taking the form of a helix, that is, of a string or cord wrapped around a cylinder, a multiple thread may be thought of as several cords lying side by side and wrapped around a cylinder. There may be any number of threads, but they must start at equally spaced intervals around a cylinder. Multiple threads are used in cases where rapid movement of the nut or other attached parts is desired and any weakening of the thread is to be avoided. A single thread having the same lead as a multiple thread would be very deep in comparison to the multiple thread.

The tool selected for cutting multiple threads has the same shape as that of the thread to be cut and is similar to the tool used for cutting a single thread except that greater side clearance is necessary. The

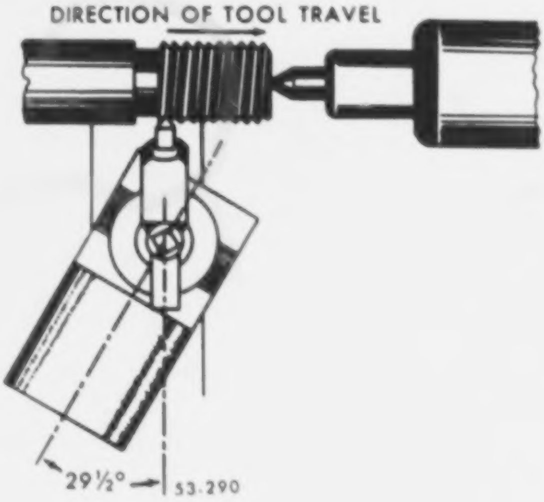


Figure 5-42. Setup for left-hand external threads.

helix angle of the thread increases with an increase in the multiple of the thread. The general method for cutting multiple threads is about the same as for single screw threads, except that the lathe must be geared to the number of single threads per inch, or with reference to the lead of the thread, and not the pitch, as shown in

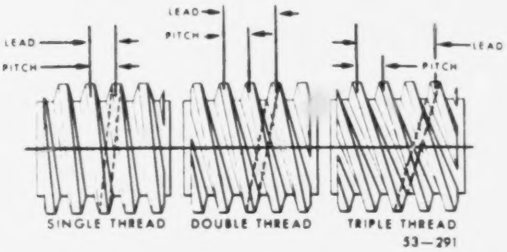


Figure 5-43. Comparison of single and multiple-lead threads.

figure 5-43. Provisions must also be made to obtain the correct spacing of the different thread grooves. This may be accomplished by using the thread-chasing dial, setting the compound parallel to the ways, using a multiple driving plate, or using the stud and box gear break up.

The use of the thread-chasing dial is the most desirable method for cutting 60° multiple threads. With each setting for depth of cut with the compound, successive cuts may be taken on each of the multiple threads so that the use of thread micrometers is made possible. To explore the possibility of using the thread-chasing dial, it is first necessary to find out if the lathe can be geared to cut a thread having a lead equal to that of one of the multiple threads. For example, if it is desired to cut 10 threads per inch, double threaded, it is necessary to divide the number of threads per inch by the multiple (in this case 10/2) to obtain the number of single threads per inch (in this case 5). The lathe is then geared for the number of single threads per inch. To use the thread-chasing dial on a specific machine, you should refer to instructions usually found attached to the lathe apron. If, for 5 threads per inch, you should engage the half nut at any numbered line on the dial, the same thread would be cut at positions 1 and 2 on the dial, as shown in figure 5-44. If the dial is then covered with the hand, leaving the part uncovered between those adjacent positions that cut the groove, positions 1 and 2 in figure 5-44, a check should be made to see if there is a point of engagement midway between positions 1 and 2 for the second thread. The second groove of a double thread lies midway of the flat surface between the grooves. There is a point of engagement in this case, position "b" in figure 5-44. For the same depth of cut, the half nut is engaged first at one of the "a" positions, then at "b" position so that alternate cuts bring both thread grooves down to size together. In the event that positions 1 and 2 would indicate the engagement place for groove of a triple thread, it would be necessary to have two positions of engagement, equally spaced, between positions 1 and 2 in order to cut the other grooves of the triple thread.

Cutting multiple threads by positioning the compound parallel to the ways should be limited to square and Acme external and internal threads, since that is the normal position of the compound for cutting those threads. The compound rest is set parallel to the ways of the lathe and the first thread is cut to the finished size. The compound and tool is then fed forward parallel to the thread axis a distance equal to the pitch of the thread and the next thread is cut, etc. Any desired multiple threads may be cut in this manner, provided that the lathe is geared to the lead of the multiple thread.

The multiple driving plate method of cutting multiple threads involves changing the position of the work between centers for each groove of the multiple thread. One method of accomplishing this is to cut the first thread groove in the conventional manner. Then the work is removed from between centers and replaced with the tail of the lathe dog in another slot of the drive plate, as shown in figure 5-45. Two slots are necessary for a double thread, three slots for a triple thread, etc. The number of multiples that can be cut by this method depends upon the number of equally spaced slots in the drive plate. Special drive or index plates are obtainable, so that a wide range of multiples may be accurately cut by this method.

Another method of cutting multiple threads is to disengage either the stud or spindle gear from the gear train in the end of the lathe after cutting a thread groove. Then turn the work and spindle the required part of a revolution, and reengage the gears for cutting the next thread. If it is necessary to cut a double thread on a lathe having a 40-tooth gear on the spindle, the first thread groove is cut in the ordinary manner.

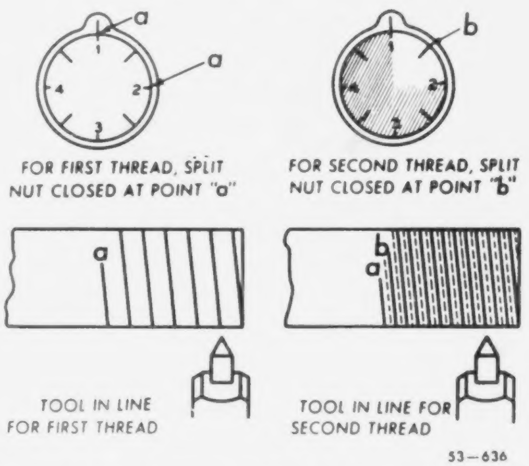

a
a
1
2
3
4
b
1
2
3
4
FOR FIRST THREAD, SPLIT NUT CLOSED AT POINT "a"
FOR SECOND THREAD, SPLIT NUT CLOSED AT POINT "b"
a
b
a
TOOL IN LINE FOR FIRST THREAD
TOOL IN LINE FOR SECOND THREAD
53—636

Figure 5-44. Cutting multiple threads using the thread-chasing dial.

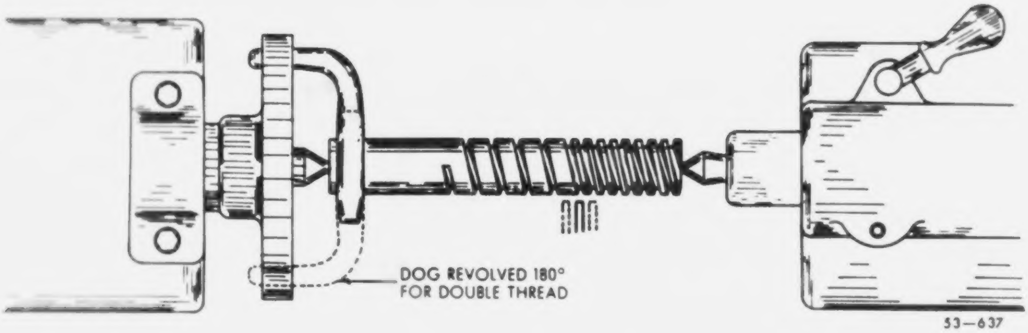


Figure 5-45. Use of slotted drive plate.

Then one of the teeth on the spindle gear that meshes with the next driven gear is marked and the mark is carried onto the driven gear, in this case the reversing gear. The tool diametrically opposite the marked spindle gear tooth (the 20th tooth of the 40-tooth gear) is marked also. The tooth next to the marked tooth should be counted as tooth number one. The gears may then be disengaged by placing the tumbler (reversing) gears in neutral position, the spindle is turned one-half revolution or 20 teeth on the spindle gear, and the gear train is reengaged. The stud gear may be indexed as well as the spindle gear. However, if the lathe does not have a 1 to 1 ratio between the spindle and stud gears, the stud gear instead of being turned as when geared for a 1 to 1 ratio would be given a proportional turn depending upon the ratio of the gearing. The method of indexing the stud or spindle gears is possible only when the number of teeth in the gear indexed is evenly divisible by the multiple desired. Some of the newer type lathes are equipped with a sliding sector gear that can be readily engaged or disengaged with the gear train by shifting a lever. Graduations on the end of the spindle show when to disengage and to reengage the sector gear for cutting various multiples.

Exercises (265):

1. Describe multiple lead threads and state why they are used.

2. How many threads per inch should a lathe be set up to cut if you want to machine a double-lead thread having 16 threads per inch?

3. Briefly describe the preferred method of cutting double lead threads.

4. Which method of cutting multiple lead threads is especially adapted to cutting Acme and square threads? Why?

266. Describe pipe thread characteristics and the procedures for cutting internal and external taper pipe threads with a lathe.

Pipe Threads. American Standard Taper Pipe Threads (NPT) are similar in form to the Unified thread; a common feature is that both have an included angle of 60°. The diameter of the threaded portion of the pipe is machined to a taper of ¾ inch per foot, and the threads are also machined at the same taper. The taper permits a tighter connection and seal between the mating threads than can be obtained with a straight thread. The nominal pipe size is the approximate inside diameter of the pipe. For example, a ⅛-27 external taper pipe thread is cut on a pipe with an outside diameter of 0.405 inch, not 0.125 inch. The ⅛ refers to the inside diameter of the pipe, whether the thread is internal or external. The actual outside diameter (the major diameter) can be found by measuring the pipe or by consulting a machinist publication.

The hole for tapered internal threads is straight-bored to a diameter equal to, or slightly larger than, the minor diameter of the small end of the mating thread. For example, the recommended tap drill size for a ¼-18 taper tap is 7/16 inch (0.4375) and the minor diameter of the small end of the thread on the mating part is 0.4329. When taper pipe threads are cut properly, the length of the taper, the length of the effective threads, and the length of the imperfect threads are all controlled according to standard dimensions. Those threads near the large end of the thread on an external pipe thread and those near the small end of internal threads are considered imperfect because they are not full size.

The most common setup for chasing tapered pipe threads on a pipe is shown in figure 5-46, but any suitable work setup can be used. Note, however, that the threading tool is positioned with the center gage aligned with the straight portion of the pipe and not with the taper. The tool setup is identical to the setup for machining Unified threads. The only difference is that the taper attachment is used when tapered pipe threads are machined. The taper attachment should be set to cut a ¾-inch per foot taper (TPF). If the taper attachment does not have a TPF scale, the degree scale can be used. The corresponding half-angle to ¾ inch TPF is 1°, 47 minutes.

90a 61

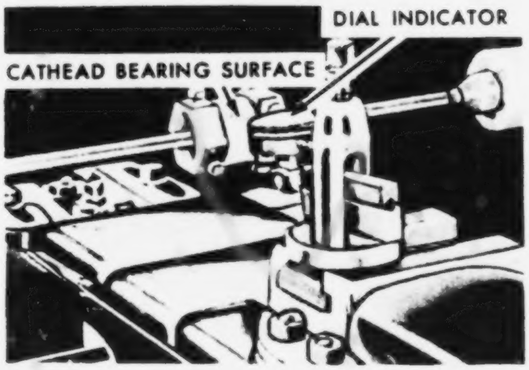


Figure 5-61. Cathead.

carriage of the lathe and hence moves with the tool, backing up the work opposite the point of tool thrust. Follower rests have two adjustable supporting jaws. One holds the work down to prevent the tendency to climb on the tool. The other is behind the work to counter the thrust of the tool.

The cutting tool may be set to precede the jaws of the follower rest for the first cut and then set to follow the jaws for the second cut. This eliminates the necessity of adjusting the jaws for each cut. The jaw adjustments are made the same as the center rest.

A follower rest is useful in turning and threading long work of small diameter. Since the diameter of the work does not change, one adjustment of the jaws is sufficient. When it is used in a threading operation, it is necessary to remove any burrs by filing. Burrs which may bear against the follower rest jaws may cause the work to revolve out of alignment.

Micrometer Carriage Stop. The micrometer carriage stop, shown in figure 5-63, is used to accurately position the lathe carriage. Move the carriage so that the cutting tool is approximately positioned and clamp the micrometer carriage stop to the ways of the lathe, with the micrometer spindle close to (but not touching) the lathe carriage. If the spindle is in contact with the carriage when you clamp the stop in place, too much pressure may be exerted on the spindle, which could damage the threads inside the carriage stop. Next, bring the carriage into contact with the micrometer spindle. NOTE: Always bring the carriage into contact with the stop by hand. Use power feed to bring the carriage within 1/32 inch of the stop, and then move the carriage the remaining distance by hand.

The micrometer carriage stop allows you to position the carriage within 0.001 inch, which is very useful when you are facing stock or machining shoulders to exact dimensions. The carriage stop also allows you to bring the tool back to the start of the cut during internal machining operations; for example, when you must remove a tool, such as an internal recessing tool, from the hole in order to take measurements and then reposition it to take additional cuts. No matter how you use the micrometer carriage stop, remember one important fact; it is a precision instrument and must be handled and cared for accordingly. It should never be thrown in a drawer with toolholders, chuck keys, etc. It should instead be stored separately in such a way that it will be protected from dust and corrosion.

Hang in there! We have one more section to go in this volume. It concerns lathe installation and maintenance. But first — you guessed it! Here are a few more questions to test your reading skills.

Exercises (273):

1. For what purpose is the center rest used?

2. What should you do to protect the work surface when using the center rest on ground work?

3. How can you use the center rest on square stock without machining a bearing surface on it?

4. Explain how the follower rest is different from the center rest.

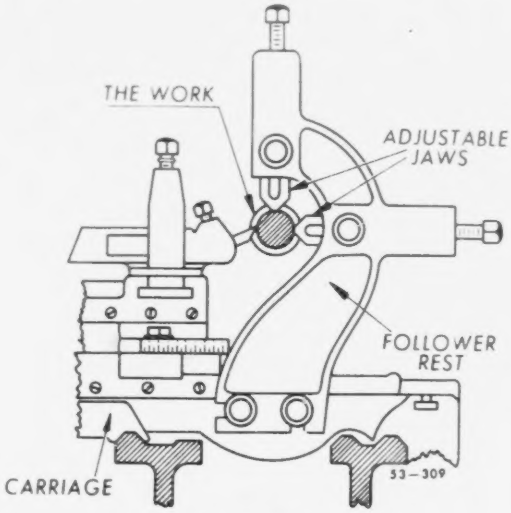


Figure 5-62. Follower rest.

5. A cutting tool can be positioned within what part of an inch when the micrometer carriage stop is used?

5-6. Lathe Maintenance

Knowing how to use a lathe is important, but it is just as important to know how to install and take care of one. A lathe is an extremely expensive piece of equipment and must be properly taken care of if it is to perform efficiently. This section is designed to help you understand how to care for a lathe.

274. List the factors to consider when installing a lathe in a machine shop.

Installation. Installation includes (1) handling of the lathe when it is received in the shop, (2) installing, and (3) leveling.

Handling. The various models of lathes require different methods of lifting. A heavy rope is better than chains or a cable for lifting the machine because it is less likely to damage the metal surfaces. If you have to use chains or a cable, pad the machine surfaces heavily to prevent damage. Leave the skids or pallet on which the lathe is mounted under the machine until it is placed in a permanent position.

Installing. Before a lathe is permanently placed in a shop, you should make a space check to insure that there is ample space around the machine so that the operator is not crowded. A floor plan or a dimensional drawing with the manufacturer's recommendations is usually furnished with the machine. Allow ample space over and above the exact size of the machine. The floor should be fairly level, with a solid foundation. In some cases it may be necessary to reinforce the floor, since vibration caused by a weak floor would cause the machine to go out of level.

Leveling. The lathe must be leveled and bolted securely to the floor to prevent distortion of the lathe bed and ways. A lathe can be leveled by driving wedges of hard wood, shingle, or shim stock between the base of the machine and the floor. Use a precision level to check the levelness of the lathe bed. A carpenter's level or a combination square level is not sensitive enough. Check the bed by placing the level crosswise on the ways at the headstock and tailstock ends. Then place the level lengthwise on the ways. It is important to check the levelness of the bed in both directions.

Exercises (274):

1. What three operations are included in lathe installation procedures?

2. If you must use chains to lift a lathe, how should you protect the metal surfaces?

3. Once you find a suitable spot for a lathe and it has been set in position, what else must be done before it can be operated?

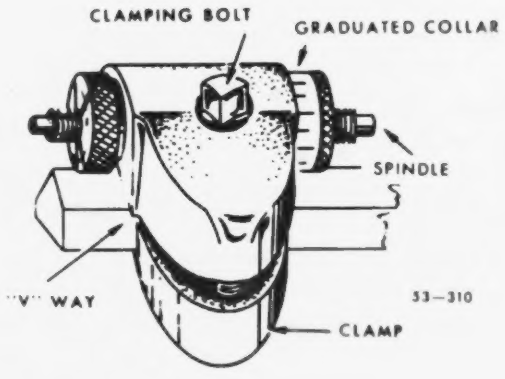


Figure 5-63. Micrometer carriage stop.

275. Specify the lubrication and maintenance requirements for lathes, including the various adjustments required to correct malfunctions.

Lathe Maintenance. Lathe maintenance is important and must not be neglected. Good maintenance makes it possible for you to get the best results in lathe operations, and it lenghtens the life of the machine. A lathe that is improperly maintained soon wears out. To keep the lathe in the best operating condition, we must make frequent inspections and various adjustments. A periodic check should be made of such things as levelness, spindle bearing condition, clutches, gibs, crossfeed and lead screws, gearing and lubrication. Adjustments should be made only when it is necessary. Since the different makes of lathes vary in their construction, it is always best to follow the manufacturer's directions on making these adjustments.

Gib adjustments. Gibs may be either tapered or flat metal bars for taking up wear between bearing surfaces, such as the dovetailed surfaces of the cross-slide, compound rest, or carriage. Gibs are provided with thrust screws by which the necessary adjustments are made. In making gib adjustments, first loosen the lockscrew. Next tighten the gib screw until a smooth snug fit is obtained. Then lock the adjustment. If gibs are adjusted too tightly, binding will result. Gibs on the compound slide should be fairly tight when the compound is not being used for cutting angles.

Headstock spindle. The spindle bearings of the newer type are generally of the nonfriction or taper roller bearing type. They are properly adjusted at the factory and need not be adjusted for long periods of time. When spindle bearing adjustments are necessary, they may be adjusted by means of a thrust nut. The adjusting nut is generally located on the rear end of the spindle, outside the headstock to allow for easy adjustment. When you make spindle bearing adjustments, place the headstock gearing in neutral so that the spindle revolves freely. Remove the back gearing guard and release the locknut or set screws that hold the thrust nut in place. With a spanner wrench provided for that purpose, turn the thrust nut clockwise until no end play is detected and the spindle can still be rotated freely by hand. A drive plate should be placed on the spindle so that the spindle may readily be rotated by hand. Adjustments on other types of bearings are essentially the same. CAUTION: Before making any spindle adjustments, make certain the trouble does not lie elsewhere. Check and make other adjustments first.

Driving clutches. The types of clutches incorporated by various lathe manufacturers may vary. Consequently the method of clutch adjustment is not the same. The more expensive precision lathes generally have the friction type of clutch similar to that of an automobile. To make adjustments of the friction-type clutch remove the clutch guardplate, pull back the adjusting pin, and rotate the adjusting yoke or ring to the right or clockwise until the pin slips into the next hole or notch. Proper adjustment is made when the clutch level snaps in and out of engagement.

Apron feed clutches. Apron feed clutches vary somewhat in design. They may consist of two friction cones or two serrated plates held together under cam pressure and released under spring tension. A thrust screw in the clutch shaft makes whatever adjustment is necessary. To adjust, turn the thrust screw clockwise until the clutch level snaps in and out of engagement.

Lead screw. The lead screw is adjusted for end play by removing the cap from the end of the screw and tightening the thrust collar. Adjustment for end play can be checked by engaging the half nut and moving the carriage, by hand, back and forth along the ways.

End gearing. To make adjustments on end gearing, remove the guard and loosen the stud nuts of the gear quadrant and mesh the gears until a slight clearance is obtained between the mating teeth. Tighten all nuts securely. Proper adjustment is made when a smooth action is obtained. No adjustment is complete until all guards have been properly replaced.

Periodic oil changes. When a lathe is run daily the oil should be changed in the headstock reservoir about every 6 months. A good grade of machine oil, SAE 20 or 30, should be used. The operator's instruction manual will state the grade of oil that should be used for the various machines. When changing oil in the reservoir, the plugs should be removed and the reservoir flushed with kerosene before refilling. The machine should be left running during the flushing process. All bearings fitted with oil cups should be oiled daily or as often as necessary. The performance of a lathe depends on the attention it receives. During the first 3 or 4 days or "the breaking in period," all bearings should be carefully oiled and watched to see that none run hot.

This will conclude Volume II after you answer these last few questions. But, don't give up yet, though. There are still two volumes left!

Exercises (275):

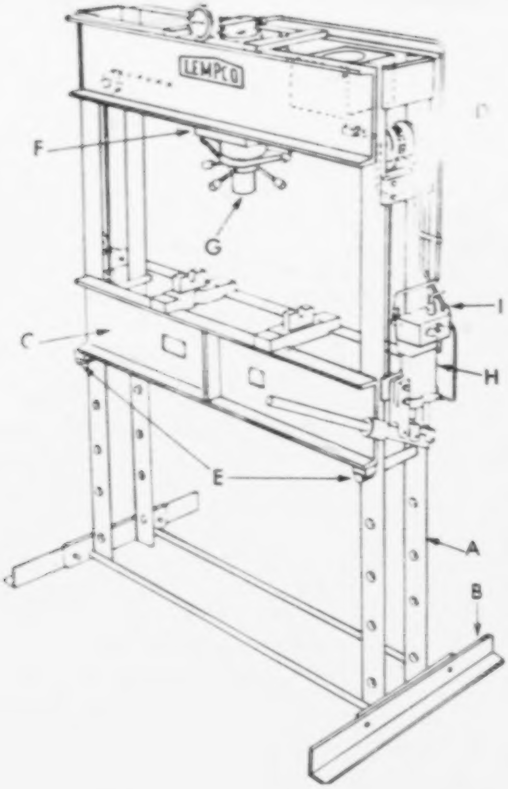
1. To be sure a lathe remains in good condition, it must be periodically checked. What things should be included in these checks?

2. Where are gibs located on the lathe?

3. What should you be sure of before you attempt to adjust spindle bearings?

4. What condition can be checked by engaging the half nut and moving the carriage back and forth by hand?

5. Describe the procedures for changing oil in the headstock.



A Frame
B Base angle
C Bolster assembly
D Hoist assembly
E Bolster pins
F Hydraulic cylinder
G Ram extension screw
H Double plunger pump
I Value block

Figure 5-64. Hydraulic press assembly (double plunge or pump type).

5-6. Hydraulic and Arbor Presses

Many tasks that you will be assigned will require the use of one type of press or another. While presses are relatively simple to operate, they do require some background information on their construction, operation, and set-up. A pressing operation may be performed before, during, or after a machining operation. For example, pressing a part on a mandrel for holding purposes prior to machining, or after machining the outside of a bushing, you may want to press it into a part and finish machining the inside diameter. Presses are used for broaching, removing and replacing parts that have an interference fit, punch and die work, and various other tasks that require pressure.

276. Given a description of a hydraulic press, identify the parts by name and state how they are used.

The Hydraulic Press. The hydraulic press consists of a welded steel frame supported by base angles which are bolted to the floor for sturdy press anchoring (see fig. 5-64). A movable bolster assembly is raised or lowered by cables and a crank operated bolster hoist. Bolster pins placed through the left and right frame siderails provide a positive support for the bolster during pressing operations. A hydraulic cylinder installed at the top of the press contains a ram extension screw which can be adjusted to contact the work surface prior to employing hydraulic pressure. An oil reservoir mounted between the frame headrails supplies hydraulic oil to a double plunger hand-operated hydraulic pump. Hydraulic pressure registers on a gage installed at the top of the cylinder.

Hydraulic cylinder. The hydraulic cylinder consists of a ram piston housed in a cylinder and bolted to the frame head rails. The ram piston is hollow to provide space for the ram extension screw in its retracted position. A handwheel and a ram screw nut, retained by steel balls, facilitate adjusting the ram adjusting screw. Rotating the handwheel clockwise extends the screw and counterclockwise retracts it. The ram piston is spring loaded and will return to its fully retracted position when the hydraulic pressure is released by turning the ram release valve. During operation of the hydraulic cylinder, hydraulic pressure that has been developed by the pump is directed to the top of the ram piston and powers the ram piston down against the work surface.

Double plunger pump. The double plunger pump consists of a pump body that has high- and low-pressure plungers, a valve block with two intakes valves, two check valves, a safety release valve, a ram release valve, and a low-pressure bypass valve. An operating level is connected to the two plungers for plunger movement. To operate the pump for pressure buildup, the ram release valve is rotated counterclockwise approximately two turns; the low-pressure "bypass" valve stem is turned counterclockwise until the stem is at rest against its stop. As the pump handle is operated, hydraulic pressure will be developed, depending on the resistance the work presents to the hydraulic cylinder. For example, if you are using a blanking die that requires a maximum of 5 tons to produce a blank, then the maximum pressure that can be built up in hydraulic cylinder is 5 tons. When approximately 10 tons of pressure has been developed, the low-pressure plunger should be bypassed to reduce the effort required by the operator. This is done by rotating the low-pressure bypass valve stem clockwise until the valve stem is at rest against its stop. This will crack open the low-pressure intake valve and prevent the low-pressure plunger from developing pressure. To build up additional pressure, the pump handle is further stroked, and only the high-pressure plunger will operate.

Low-pressure intake and bypass. The low-pressure intake and bypass valve is a spring-loaded ball check in the valve block. This valve serves two functions.

First, it serves as an intake valve on the down stroke of the low-pressure plunger. Second, it serves as a bypass valve at pressures above 10 tons. When the valve stem has been rotated counterclockwise against its stop, intake oil passes through the valve and charges the low-pressure plunger bore on the down stroke of the low-pressure plunger. On the up stroke, hydraulic pressure automatically closes the intake valve and opens a high-pressure valve that is on the low-pressure side of the valve block. This completes the circuit connecting the low-pressure plunger to the ram piston. When the low-pressure bypass valve stem is turned clockwise against its stop, the intake valve ball is unseated and oil is bypassed to the oil reservoir. By allowing the oil to bypass the low-pressure pump, it will be much easier to operate the pump level at pressures above 10 tons.

High-pressure intake valve. The high pressure intake valve is just a spring-loaded ball check valve used for supplying oil to the high-pressure plunger bore on the down stroke of the pump. On the down stroke of the high-pressure plunger, oil passes through the intake valve and fills the high-pressure plunger bore. On the up stroke, hydraulic pressure is built up and causes the intake valve to close and the high-pressure check valve to open. This completes the circuit of oil flow that connects the high-pressure plunger to the ram piston.

High-pressure check valves. There are two high pressure check valves located in the pump valve block. These valves are spring-loaded ball check valves located on the low- and high-pressure sides of the pump valve block. The function of the two valves is to provide a means of connecting both pump plungers to the ram piston, whereby the connecting circuit automatically opens and closes as a function of hydraulic pressure.

Safety relief valve. A safety relief valve is built into the pump valve block of the double plunger pump and is set at the factory to open when the press reaches its rated capacity. (NOTE: If the safety relief valve opens prematurely, check the operator's manual or TO for proper adjustment procedures.)

Ram release valve. The ram release valve is located on the high-pressure side of the pump valve block. The purpose of this valve is to provide a port in the high-pressure circuit of the pump and cylinder that may be opened or closed manually. It is by this valve that you allow hydraulic pressure to build up for a press operation and also to release the pressure when the press operation is complete.

Oil reservoir. An oil reservoir, of approximately 1 gallon capacity, is mounted between the frame headrails. The reservoir supplies oil to the pump. A fine mesh strainer is installed below the reservoir cover to catch impurities during filling.

Bolster. The bolster assembly is used to support the work during pressing operations and is raised or lowered by cables attached to the bolster hoist. The bolster must be resting on the bolster pins when ram pressure is applied.

CAUTION: Do not apply ram pressure against the bolster when it is suspended only by cables.

When the bolster has been raised or lowered and the bolster pins reinstalled, you should put some slack in the cables to make sure the bolster is resting on the bolster pins. This will help prevent overstressing the bolster cables.

Exercises (276):

1. Name the three major parts of the pump assembly.

2. What causes pressure to build up in the hydraulic press?

3. When should the low-pressure plunger be bypassed? Why?

4. Why is a ram piston hollow?

5. Explain why a ram piston is spring-loaded.

6. What two functions does the low-pressure intake and bypass valve serve?

7. What closes the intake valve and opens the high-pressure valve on the upstroke?

8. What happens during the down stroke of the high-pressure plunger?

9. What happens during the upstroke of the high-pressure plunger?

10. What is the purpose of the safety relief valve?

11. What precaution should you take after raising or lowering the bolster assembly?

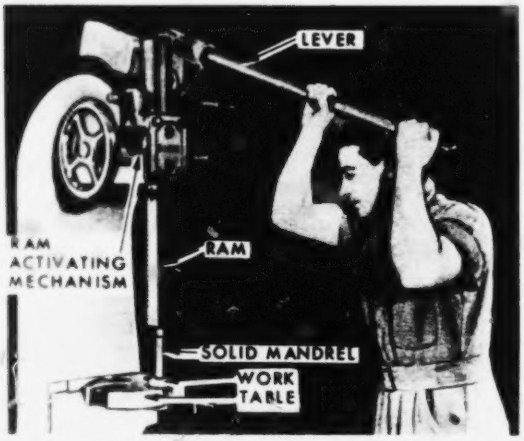


Figure 5-65. Using an arbor press to install a mandrel.

277. State the specific procedures involved in setting up and operating the hydraulic press.

Operation of the hydraulic press is quite simple, once the press has been properly set up for pressing operations. The hydraulic press is set up and operated in the following manner.

a. Roughly estimate the height of the part or parts that you need to press, then pull the bolster pins and raise or lower the bolster as necessary. Reinstall the bolster pins and slack off the cables. It is best to have the bolster as close to the ram as possible and still be able to press your parts.

b. Turn the ram release valve stem counter clockwise two revolutions.

c. Turn the low-pressure bypass valve stem counterclockwise until the stem rests against its stop pin.

d. Place part or parts on bolster and set up any special adapters or plates required for a pressing surface.

e. Adjust the ram extension screw until the ram contacts the pressing surface. Turning the handwheel clockwise extends the screw and counterclockwise retracts the screw.

f. Operate the pump to produce the required pressure and stop the pumping operation after the pressing operation has been completed.

NOTE: If hydraulic pressure of more than 10 tons is required, or whenever you desire to reduce the effort required when pumping, turn the low-pressure bypass valve stem clockwise until it rests against its stop pin. This will bypass the low-pressure plunger that requires the most effort as pressure builds up.

g. When your press operations are complete, turn the ram release valve stem two turns clockwise to release the hydraulic pressure in the cylinder. The cylinder is spring-loaded and will return to its retracted position.

h. If the press becomes dirty, greasy, or oily with use, wipe clean with a cloth moistened in cleaning solvent.

Exercises (277):

1. How close should the bolster be to the ram when setting up the hydraulic press?

2. How far is the ram adjusted prior to pressing a part?

278. Cite the uses and procedures in applying pressure or force when using an arbor press.

Arbor Press. The arbor press is a simple machine for applying pressure to remove shafts from gears or pulleys or to press a bearing, shaft, or mandrel into a hole. It is used extensively to assemble parts, such as bushings, pins, and shafts which require a press or force fit. The arbor press is also used to straighten small shafts, broach keyways, and to dimple sheet metal. The list of tasks that can be performed using an arbor press is limited only by the user's knowledge and imagination. Listed below are some of the common uses that you as a machinist will be required to know.

Installing a mandrel. On occasion you may be required to install a mandrel, as shown in figure 5-65. The key to pressing a mandrel, or any other parts for that matter, is to make sure the parts are sitting flat on the worktable and in alignment with each other. They must also be in line with the travel of the ram, so that the ram can press squarely on them to help insure a smooth, even press that does not gall the pressed part. As an additional aid in the pressing operation, you can use a lubricant on the press fitted area to further prevent galling.

Straightening small shafts. Occasionally you will be required to repair a shaft that has been bent accidentally. If it isn't in too bad condition and isn't cracked or broken, it probably will be easier to straighten it in the following manner, rather than make a new one. In addition to the arbor press, you will need a straight edge and a set of "V" blocks.

Place the "V" blocks on the table of the arbor press with the bent shaft lying in the matching "V"s. Slide the "V" blocks away from each other until the bent portion of the shaft rests between the blocks and directly below the ram. Also, make sure the ram can pass evenly between the "V" blocks, because to straighten the shaft you must bend it slightly beyond its centerline. Next, position the bent portion up towards the ram. Bring the ram down and rest it against the highest part of the bend. Using the ram, press the bent portion down until it travels slightly beyond the centerline of the shaft. You must force the centerline of the shaft to curve down slightly during the straightening process because of the shaft's tendency to spring back. Check your work by laying a straightedge against the top of the shaft and parallel to the centerline of the shaft. With the straightedge against the shaft, check for light to show between the two edges. Rotate the shaft twice at 120-degree intervals and check with the straightedge each time. Repeat pressing operation until no light is visible between the straightedge and the shaft or until it is within prescribed limits. You can check the amount of gap between the straightedge and the part by inserting a feeler gage that just barely fits into the gap. You must remember that if you have a .002 inch gap, you'll have a total of .004 inch of run-out when the shaft is spinning.

Anti-friction bearings. You will have to remove and replace a variety of different antifriction (ball or roller type) bearings when repairing parts. You must be especially careful when performing this task because these types of bearings are easily damaged. You should press against the race that is press fitted, whenever possible. That is, if the bearing is pressed into a hole, you should press against the outer race to remove or replace it. This will help to prevent damaging the moving parts of the bearing.

Exercises (278):

1. What should you always make sure of before you press a part?

2. Where should you press, when pressing an anti-friction bearing?

3. Why would you use a lubricant when pressing parts?

Bibliography

Books

Oberg, Jones, and Horton. *Machinery's Handbook,* 20th Edition. New York: Industrial Press, 1976.

Colvin, Charles H., Henry F. Colvin, and Eleanor Stanley. *The New American Machinist's Handbook.* New York: McGraw Hill Book Company, 1973.

Walker, John R. *Modern Metalworking.* Illinois: The Goodheart-Willcox Company, Inc. 1973.

Department of the Air Force Publications

AFR 127-101, *Accident Prevention Handbook.*

TO 1-1A-9, *Engineering Series for Aircraft Repair-Aerospace Metals-General Data and Usage Factors.*

TO 34G1-5-11-1, *Arbor Press, Hydraulic and Mechanical.*

TO 34-1-10, *Fundamentals of Ordnance Corps Machine Tools.*

TO 42B-1-6, *Corrosion Prevention Lubricants and Anti-Seize Compounds.*

TO 42B2-1-3, *Fluids for Hydraulic Equipment.*

NOTE: None of the items listed in the bibliography above are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell AFB AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only *books* and a limited number of *AFMs.* TOs, classified publications, and other types of publications are *not* available. Refer to current indexes for the latest revisions of and changes to the official publications listed in the bibliography.

261 - 3. It could cause burns or cuts.

262 - 1. It is the angle formed by the inclination of the thread and a plane perpendicular to the thread axis.

262 - 2. Pitch is the distance from a point on one thread to a corresponding point on the next thread measured parallel to the axis, while pitch diameter is measured at a right angle to the axis and is the diameter of an imaginary cylinder whose periphery passes through the thread at a point where the width of the thread and thread groove are equal.

262 - 3. ¼ = nominal diameter
28 = number of threads per inch
UNF = Unified fine
3 = thread class-lowest tolerance of the three classes
B = internal thread

262 - 4. It denotes the thread class of fit (close) and the fact that it is an internal thread.

263 - 1. The thread gage is a go and no-go type gage in which the thread is correctly machined when it fits the "go" portion of the gage but not the "no-go" portion. The thread micrometer measures the pitch diameter of a thread.

263 - 2.

$$M = \frac{MD - 1.5155}{\text{No. threads}} + (3W)$$

$$M = 0.250 - \frac{1.5155}{20} + (3 \times 0.029)$$

$$M = 0.250 - (0.07577) + (0.087)$$
$$M = 0.17423 + 0.087$$
$$M = 0.2612 \text{ inch}$$

264 - 1. They are used when the direction of motion is required to be opposite of right-hand threads and when slippage between the part and nut would tend to loosen a right-hand thread.

264 - 2. The relief and rake angles are reversed on left-hand thread cutting tools.

264 - 3. The area at the start of the thread should be undercut to a depth slightly more than the single thread depth and wide enough to allow the threading to have starting room. The first thread should also be chamfered.

265 - 1. Multiple lead threads are two or more threads which are parallel to each other and are cut around the same surface. They are used where rapid movement of the nut or attached part is desired but where thread strength must be maintained.

265 - 2. Eight threads per inch.

265 - 3. Use of the thread-chasing dial is the most preferred method. By locating two adjacent points of thread engagement on the dial face for the single threads per inch, you can then locate a point of engagement half way between those two points which will produce the other thread to form a double thread. For a triple thread lead, you would choose two points equally spaced between the first two, etc.

265 - 4. The preferred method is to position the compound rest parallel to the ways because that is the way that square and Acme threads are cut even when they are not cut in multiples.

266 - 1. Both thread forms have included angles of 60°.

266 - 2. Taper pipe threads are machined on a taper of 3/4 inch per foot.

266 - 3. It is positioned in relation to the axis of the work and not in relation to the tapered surface that is to be threaded.

266 - 4. It should be straight bored to a diameter equal to or slightly larger than the minor diameter of the small end of the pipe.

267 - 1. The depth of an Acme is equal to one-half the pitch, plus clearance allowance, and the sides form an included angle of 29°.

267 - 2. The tool should be ground to fit a thread one pitch size smaller than the thread to be cut. It should have 3° to 6° more side clearance than the helix angle of the thread and have 0° side and back rake. The tool should be aligned the same way as for Unified threads, but the compound rest should be set parallel to the ways.

267 - 3. The sides of a square thread are parallel and the depth is equal to the width of the space between the teeth on external threads. On internal threads, the width of the space between the teeth is slightly wider than the depth for clearance.

267 - 4. The internal threading tool must be slightly wider than the one for internal threading.

267 - 5. The tool bit is fed straight into the work and the compound rest is set parallel to the ways.

268 - 1. Change it from millimeters to threads per inch.

268 - 2. $6{:}\ \frac{25.4}{4} = \frac{6 \times 4}{25.4} = \frac{24}{25.4} = $ the desired ratio

$$\frac{24}{25.4} \times \frac{5}{5} = \frac{120}{127} = \begin{array}{l}\text{driving gear}\\ \text{driven gear}\end{array}$$

268 - 3. You multiple the number of teeth on the spindle gear by the number of threads per inch to be cut. Then you divide that by the number nearest to the desired TPI on the quick change gearbox that will make the dividend an even number.

269 - 1. 10 to 30 rpm.

269 - 2. By a tap wrench which is rested on the compound rest.

269 - 3. By light pressure from the end of the tailstock spindle, a drill pad or the jaws of a drill chuck in the case of very small dies.

269 - 4. Insert the chasers into the designated slots, set the desired size (pitch diameter), set the rough/finish lever to "R" and insert the tapered shank into the lathe tailstock. Slide the tailstock carefully toward the chamfered stock. As the die begins to cut, slide the tailstock along with it. Pull backward on the "tailstock to open it. Reset the die to the "F" setting and repeat the cutting steps.

270 - 1. For making impressions into the work surface for decoration or to provide a gripping surface.

270 - 2. The knuckle joint type has two rollers in a swivel-type knuckle; the revolving head type has three sets of rollers that can be moved into position by revolving the roller mounting head; and the straddle type has two rollers mounted in jaws that can be opened or closed with an adjusting screw.

270 - 3. There are two patterns, diamond and straight; and there are three pitches for each pattern, fine, medium, and coarse.

270 - 4. Making the setup sturdy enough to support the knurling pressure.

270 - 5. Back the knurling tool away with the cross-slide, reposition it, and start again in a new spot.

270 - 6. Set the tool up as always, but before you start knurling, set the compound rest 30° to the right. This will cause only the right-hand corner to contact the work a little to the left of the right-hand layout line. If it tracks properly, extend the knurl to the layout line. Then move the tool back, position the compound rest back to the original setting and resume the knurling operation.

271 - 1. The centering holes in the grinding wheel spindle should be aligned with the head or tailstock centers.
271 - 2. They are mounted on tapered shafts called quills.
271 - 3. An exploding wheel because of running at too high an RPM.
271 - 4. It should be mounted in a holder which is clamped to the faceplate. The point of the dresser should be set at center height and angled 10° to 15° in the direction of wheel rotation.
271 - 5. Move the wheel away from the work.

272 - 1. On tension springs, the coils lie one against the other in the free state; on compression springs, the coils lie at a set distance apart in the free state. The tension offers resistance to being pulled apart while the compression spring offers resistance to being pressed together.
272 - 2. Steel containing about 1 percent carbon and little or no sulfur or phosphorous.
272 - 3. Phosphorus bronze wire.
272 - 4. The wire is passed through two wood or brass blocks which are pressed together enough to keep the wire tight on the mandrel. The wire is then pulled onto the mandrel by the rotation of the mandrel during the operation.

273 - 1. To prevent springing of slender stock; to provide auxiliary support to permit heavier cuts; to provide support for drilling, boring, or internal work.
273 - 2. Use copper shims between the work and the center rest jaws.
273 - 3. By mounting a cathead on the work.
273 - 4. The follower rest has only two jaws and is mounted to the carriage instead of the ways of the lathe.
273 - 5. 0.001 inch.

274 - 1. Handling, installing, and leveling.
274 - 2. Pad the machine surfaces where the chains will contact the machine.
274 - 3. It must be leveled and then bolted to the foundation.

275 - 1. Such things as lubrication, levelness, bearing condition, gearing, lead screw condition, gibs, and clutches.
275 - 2. On dovetail surfaces of the carriage, cross-slide, and compound rest.
275 - 3. That the trouble does not lie somewhere else.
275 - 4. The end play in the lead screw.
275 - 5. The drain plugs should be removed and then, with the machine running, the reservoir should be flushed with kerosene. Then the plugs should be replaced and the reservoir filled with a good grade of oil in accordance with the operator's manual.

276 - 1. Pump body, valve body, and operating lever.
276 - 2. The resistance the work presents to the hydraulic cylinder.
276 - 3. When approximately 10 tons pressure has been built up. To reduce operator effort.
276 - 4 To allow for the ram extension screw.
276 - 5. To retract the ram piston when the hydraulic pressure is released.
276 - 6. Intake valve on the down stroke of the low pressure plunger and a bypass valve at pressures above 10 tons.
276 - 7. Hydraulic pressure.
276 - 8. Oil passes through the intake valve and fills the high pressure plunger bore.
276 - 9. Hydraulic pressure is built up, causing the intake valve to close and the high pressure check valve to open.
276 - 10. To prevent the press from exceeding its rated capacity.
276 - 11. Put some slack in the bolster cables to prevent them from being over stressed.

277 - 1. As close as possible.
277 - 2. Until the ram contacts the pressing surface.

278 - 1. The parts are sitting flat and in alignment.
278 - 2. Against the race that is to be press fit.
278 - 3. To prevent galling.

CHANGES FOR THE TEXT: VOLUME 3

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
Front cover			Change "(AFSC 53150)" to "(AFSC 42750)."
1	NOTE at top of page	last	Change "object" to "objective."
1R		10,11,12	Change sentence to read "you usually use hand feed to take the depth of cut or to accurately position the work, and you use power feed to move the work smoothly during machining operations."
1R		20	Change "speed" to "feed."
9L		19	Change "0.0001" to "0.001."
11R		3	Add comma between "milling" and "two."
14R		3,4	Delete sentence beginning with "The slotting . . ." and ending with "attachment."
15L	Exercises (406)		Add between 406-2 and 406-4: "3. When you set up a slotting attachment, how do you set the number of strokes per minute?"
16L		17 fr bot	Delete "work and."
16R		9	Change "plus" to "minus."
16R		16	Change "reamer" to "cutter."
16R		23	Change "clears" to "will clear."
17R		last	Change "center" to "cutter."
18L		15 fr bot	Change "keyslot" to "key."
19R		13 fr bot	Change "radio" to "ratio."
19R		11 fr bot	Change "50 to 1" to "5 to 1."
24L		10 fr bot	Delete.
32R		29 fr bot	Change "Several" to "Most."
32R		28 fr bot	Change "on" to "of."
32R		14 fr bot	Change "is" to "in."
34R		18 fr bot	After sentence ending with "part work" add "and to cut narrow slots."
36L		2 ft bot	Change "Also" to "However."
36R		20 fr bot	After "are" insert "two."
36R		13 fr bot	Change "are" to "can be."
37R		8	Change "table" to "vise."
38R		10 fr bot	Change "tool clears" to "tool and toolslide clear."
38R	Formula		Change formula to read as follows: $N = \frac{CFS \times 7}{L}$
39R		1	After "consulting" insert "figure 2-16 or."
39R		2 fr bot	Change "you" to "To machine vertical and some angular surfaces, you can."

Page-Col	*Subject*	*Line(s)*	*Correction*
40R		24 fr bot	Insert ", toward the operator's side of the shaper," after "right."
42L		3	Change "position" to "positions."
45R		2 fr bot	Change "they" to "the."
46L		8-11 fr bot	Delete entire sentence beginning with "Measure the depth . . . ."
47R		23	Insert "degree" between "toolhead" and "graduations."
47R		30	Delete second "to."
49L		1	Change "imporve" to "improve."
50R		6	Change "floor" to "flood."
52R		16	After "material" insert "do not."
52R		24	After "finish." add "A medium spacing is best for general-purpose wheels."
57R		15,16 fr bot	Change "spindle" to "grinding wheel."
59L	429-2	2	Change "2.250" to "2,250."
61L		3	Place the number "431" before the behavioral objective statement.
62L		5	Add above the first line of formula: table traverse = (1 × ¼ × 300) ÷ 12
62R	431-4	1	Change "1.5-wide" to "1.5-inch-wide."
75L		18 fr bot	Change "AFSC 531X5" to "AFSC 427X2."
77R		29 fr bot	Change "then the external part" to "than the diameter into which it fits."
84L	410-3	2	Change "12$\frac{1}{1}$ turns" to "12½ turns."
84L	412-6	2	Change "therms" to "terms."
84L	409-10	3	After "the" insert "same or."
86L	431-5		Move "431-5." up one line (to line 3).
86R	438-3	1	After "teeth" add "on form."
86R	443-1	2	Change "than" to "that."

Page Changes: Remove old pages and insert new pages as indicated. If the replacement pages number more than those they replace, those pages in excess of the pages being replaced will carry letter designations. For example: 20, 20a, 20b, etc.

Remove Pages	*Insert Pages*
iii-iv	*iii-iv*
3-4	3-4c
21-22	21-22
43-44	43-44
53-56	53-56b
63-64	63-64 a
67-68	67-68 a

Preface

YOU ARE NOW starting the second half of CDC 53150, Machinist. This third volume covers advanced machine work. Chapter 1 covers milling machine work and Chapter 2 covers shaper work. Chapter 3 is concerned with the various types of grinding operations that you may be required to do, and Chapter 4 is concerned with the various aspects of fitting and assembling machined parts.

Code numbers appearing on figures are for preparing agency identification only and should be of no concern to the student.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: Tech Tng Cen/TTGXW; ATTN: SMSgt John D. Wurm, Chanute AFB IL 61868. If you need an immediate response, call the author, AUTOVON 862-2385, between 0800 and 1600 (CST), Monday through Friday. *NOTE: Do not use the suggestion program to submit changes or corrections for this course.*

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this person can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of July 1981.

Contents

Page

Preface iii

Chapter

1 Milling Machine Work 1

2 Shaper Work 34

3 Grinding Machine Work 51

4 Fitting and Assembly 75

Bibliography 82

Answers for Exercises 83

should extend the overarm only far enough to position the arbor support over the arbor bearing and keep the setup as rigid as possible. Tighten the locknuts after you have positioned the overarm, C. You can further increase the rigidity of an arbor setup by using overarm braces like those shown in figure 1-1, V. On some milling machines, the collant supply nozzle is fastened to the overarm. In most cases, the nozzle holders are designed with split clamps so that they can be easily added to the setup after the arbor support has been locked into position.

Arbor support. The arbor support is a casting that contains a bearing which aligns the outer end of the arbor with the spindle. This helps to keep the arbor from springing during cutting operations. Two types of arbor support are commonly used. Type A, figure 1-1, B, has a small-diameter bearing hole. Type B, figure 1-1, A, has a large-diameter bearing hole. An oil reservoir in the arbor support supplies the bearing surfaces with the necessary lubrication. You can clamp an arbor support at any location on the overarm. A type A arbor support provides more clearance beneath it than does a type B. This is important when small diameter cutters are being used on the arbor or when the depth of cut brings the arbor close to the work piece. However, type A arbor supports can provide support only at the extreme end of the arbor and are therefore not recommended for general use. You can position a type B arbor support at any position on the arbor. This feature allows the arbor support to be positioned close to the cutter, and this greatly increases the rigidity of the setup.

NOTE: Before loosening or tightening the arbor nut, you must install the arbor support. This will prevent bending or springing the arbor.

Exercise (400):

1. Match the most appropriate statement (description or purpose) on the right with the milling machine part (on the left) to which it applies. More than one statement may apply to some parts.

_____1. Column.
_____2. Knee.
_____3. Power feed mechanism.
_____4. Table.
_____5. Spindle.
_____6. Overarm.
_____7. Arbor support (type A).
_____8. Base.
_____9. Arbor support (type B).

a. It holds and drives the cutter.
b. It is contained in the knee and permits the table to be moved by power.
c. It contains an oil reservoir.
d. The saddle is mounted on it.
e. It extends completely through the column.
f. An adjustable horizontal beam.
g. It contains T-slots for mounting work.
h. It has a small diameter bearing hole for certain arbors.
i. It can be moved longitudinally along the saddle.
j. It can be positioned next to the cutter on an arbor.
k. It contains a coolant pump.

401. Describe the characteristics and application of selected types of milling cutters and arbors.

Milling Cutters. Figure 1-1a shows the parts and terminology of milling cutters. These cutters come in a variety of types and sizes. *Plain milling cutters* are used to mill flat surfaces that are parallel to the cutter axis. The *side milling cutter* is a plain milling cutter with teeth cut on both sides, as well as on the circumference of the cutter. You can see in figure 1-2,A, that the portion of the cutter between the hub and the side of the teeth is thinner to provide additional chip clearance. These cutters are often used in pairs to mill parallel sides, called straddle milling. Cutters over 8 inches in diameter usually have inserted teeth. The size designation is the same as for plain milling cutters. Some side milling cutters have coarse, helical teeth on one side only. These cutters are made particularly for jobs where only one side of the cutter is needed.

As you can see in figure 1-2,B, a plain milling cutter is a cylinder with teeth cut on the circumference only. Plain milling cutters are made in a variety of diameters and widths with the cutter teeth either straight or helical. If the width is more than 3/4 inch, the teeth are usually helical. On a straight cutter, each tooth cuts along its entire width at the same time, causing a shock as the tooth starts to cut. Helical teeth eliminate this shock and produce a free cutting action. A helical tooth begins the cut at one end and continues across the work with a smooth shaving action. Course tooth cutters (cutters with large chip spaces) are better for

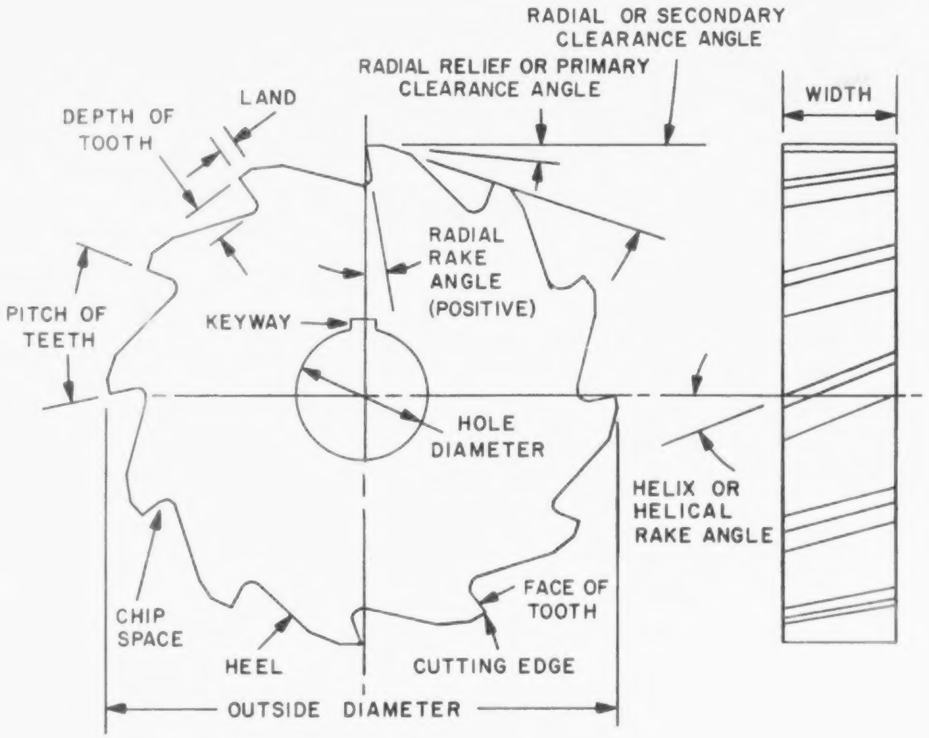

RADIAL OR SECONDARY CLEARANCE ANGLE
RADIAL RELIEF OR PRIMARY CLEARANCE ANGLE
WIDTH
LAND
DEPTH OF TOOTH
RADIAL RAKE ANGLE (POSITIVE)
PITCH OF TEETH
KEYWAY
HOLE DIAMETER
HELIX OR HELICAL RAKE ANGLE
FACE OF TOOTH
CHIP SPACE
HEEL
CUTTING EDGE
OUTSIDE DIAMETER

Figure 1-1a. Milling cutter terminology.

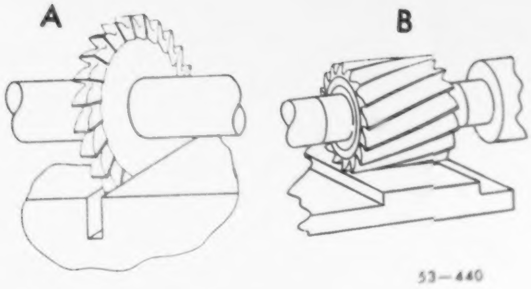


Figure 1-2. Side and plain milling cutters.

use on ductile materials, since they allow an easier flow of chips through the chip space than do fine tooth cutters (cutters with small chip spaces). Fine tooth cutters are more efficient for cutting thin materials, since they reduce vibration and the tendency for the cutter teeth to straddle the workpiece and dig in. On some coarse helical tooth cutters, the tooth face is undercut to produce a smoother cutting action. Some also have alternating nicks cut into the cutting edges of the teeth. The nicks are designed to break up long, continuous chips. A plain milling cutter has a standard size arbor hole for mounting it on a standard size arbor. The size of the cutter is designated by the diameter of the cutter, the width of the cutter, and the diameter of the hole.

A type of cutter that is similar to the plain or side milling cutter is the *metal slitting saw,* which is used to cut off work and to mill narrow slots. The face width is usually less than 3/16 inch. This type of cutter usually has more teeth for a given diameter than a plain cutter. It is thinner at the center than at the outer edge to provide proper clearance for milling deep slots. In many slitting saws, the teeth are cut only in the circumference while others have side teeth to achieve better cutting action, break up chips, and prevent dragging when you cut deep slots. For heavy sawing in steel, there are metal slitting saws with staggered teeth. These cutters are usually 3/16 inch to 3/8 inch in thickness.

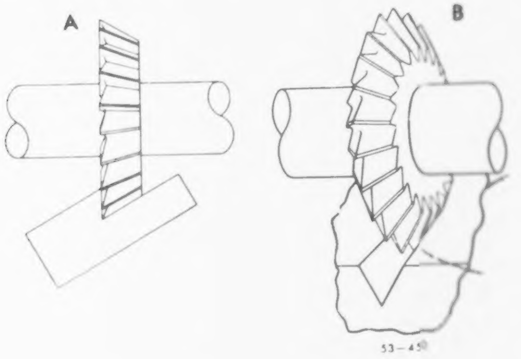


Figure 1-3. Angle cutters.

You will use *angle cutters* to mill surfaces that are not at a right angle to the cutter axis. You can use angle cutters for a variety of work, such as milling reamer flutes and dovetail ways. On such work as dovetailing, where you cannot mount a cutter in the usual manner on an arbor, you can mount an angle cutter that has a threaded hole or is constructed like a shell end mill on the end of a stub or shell end mill arbor. When you select an angle cutter, you should specify type, hand, outside diameter, thickness, hole size, and angle.

There are two types of angle cutters: single and double. In the *single angle* cutter, shown in figure 1-3,A, the teeth are cut at an oblique angle with one side at an angle of 90° to the cutter axis and the other usually at 45°, 50°, or 80°. When selecting a single angle cutter, you must also consider the "hand" of the cutter. A single angle cutter is considered to be a right-hand cutter if it revolves counterclockwise (left-hand cutter if it revolves clockwise) when cutting as viewed from the side of the larger diameter. The *double angle* cutter, figure 1-3,B, has two cutting faces at an angle to the cutter axis. If both faces are at the same angle to the axis, you obtain the cutter you want by specifying the included angle. In this case, you would not specify the hand of the cutter, since this type of cutter can be used as either right hand or left hand. However, if the faces of the cutter are at different angles to the cutter axis, you must specify the hand of the cutter as well as the angle of each side with respect to the plane of intersection.

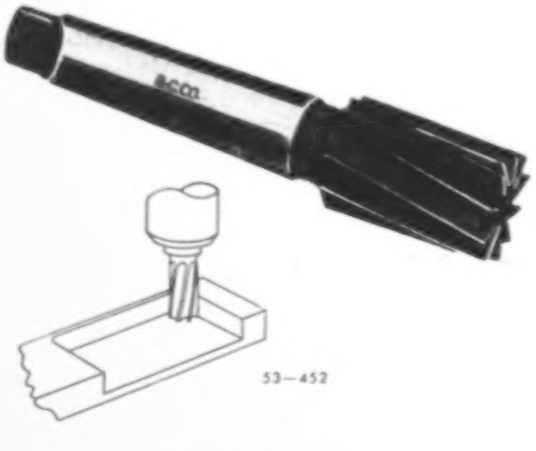


Figure 1-4. End Mills.

You will use *end mill cutters* to mill slots, tangs, and the ends and edges of work. Teeth are cut on the end as well as on the circumference of the cutter. The cutters may be solid with two or more teeth or they may be the shell type. The two-lipped end mill is especially adapted for milling slots without first drilling a hole. It should be used mainly on softer, nonferrous metals and should be operated at a fairly high speed. Figure 1-4 shows a center cutout end mill. You can use this cutter to mill work to a depth of cut equal to the length of the end teeth. *Shell end mills,* shown in figure 1-5, are attached at the end of a taper shank arbor. For long production runs, they can be more economical than large solid cutters because they are cheaper to replace when they break or wear out. Inserted blade cutters can be even more economical for this type of operation, since only the worn or broken blades (teeth) are replaced.

A *Woodruff keyseat cutter,* figure 1-6, is used to cut curved keyseats. A cutter with less than a 1½ inch diameter has a shank. If the diameter is greater than 1½ inches, the cutter is usually mounted on an arbor. The staggered teeth on the larger cutters improve the cutting action.

Involute gear cutters (fig. 1-7) are used on standard milling machines to mill teeth on spur gears, bevel gears, and helical gears. The word "involute" simply refers to the ideal curvature of the side of a gear tooth. In actuality, an involute gear cutter cuts the proper curvature only in the area around the pitch diameter (even on simple spur gears). However, the rest of the tooth dimensions will be accurate enough for most general uses.

There are eight standard involute gear cutters commonly available, as shown in figure 1-7a. Each cutter is designed to cut the best tooth shape for the smallest number of teeth of those listed (a number 7 cutter cuts the best tooth shape on a gear with 14 teeth). However, all the numbers of teeth listed for each cutter can be produced with generally acceptable tooth shape. When greater accuracy of tooth shape is required on gears where the number of teeth is between the "best" numbers for the cutters listed, a series of seven intermediate cutters are available. For example, a number 7½ cutter is designed specifically to cut gears with 13 teeth. These cutters, however, are not commonly used for cutting general-purpose gears.

The standard series of cutters shown in figure 1-7a is also used to cut helical gears with a milling machine. However, there is one major difference in the cutter selection process between spur gears and helical gears. In helical gear cutting, you must select a cutter with reference to a "calculated" number of teeth instead of the actual number of teeth, as in spur gearing. The calculated number of teeth takes into account the lead angle on the tooth profile, the normal diametral pitch, and the cutter diameter. For example, to cut a helical gear with 15 teeth, you would use a number 5 cutter instead of the number 7 cutter that figure 1-7a shows. The formulas for determining which cutter to use in helical gearing can be found in machinist publications such as the *Machinery's Handbook.*

A different series of eight standard involute gear cutters is used to machine teeth on straight bevel gears. These cutters are similar to the spur gear cutters, except that they are thinner to allow them to pass through the narrow tooth space at the small end of the bevel gear. We will discuss the bevel gear cutting process in greater detail later in this chapter. Helical bevel gears are almost impossible to machine accurately on a milling machine. They must be "generated" on helical generating machines which are not commonly used in the Air Force because of their great expense.

Cutter number	Number of gear teeth
1	From 135 to rack
2	55 to 134
3	35 to 54
4	26 to 34
5	21 to 25
6	17 to 20
7	14 to 16
8	12 to 13

Figure 1-7a. Standard involute gear cutters.

Figures 1-8 and 1-9 show a *concave cutter* and a *convex cutter* respectively. Remember that a concave cutter is used to cut a convex surface, and a convex cutter is used to cut a concave surface. A variation of the concave cutter is the *corner rounding cutter.* It is essentially one-half of a concave cutter and is used to round corners up to one-quarter of a circle.

A high degree of accuracy can be obtained by using a *gear hob,* as shown in figure 1-10. This special type of cutter is used on a gear hobbing machine and can cut spur gears, helical gears, worm gears, ratchets, and splined shafts.

Arbors. Milling machine cutters can be mounted on several types of holding devices. You must know what the devices are and the purpose of each to make the most suitable tooling setup for the operation you are performing. We will cover the various types of arbors and the mounting and dismounting of arbors.

NOTE: Technically, an arbor is a shaft on which a cutter is mounted. For convenience, since there are so few types of cutter holders that are not arbors, we will refer to all types of cutter holding devices as arbors.

There are several types of milling machine arbors. You use the common or standard types, shown in figure 1-11, to hold and drive cutters with mounting holes.

The most common arbors have a standard milling machine spindle taper of 3½ inches per foot. The largest diameter of the taper is identified by a number. For example, the large diameter of a number 40 milling machine spindle taper is 1¾ inches. The numbers designating the sizes of common milling machine spindle tapers are:

number of degrees you need can be divided into 360° and when the quotient you obtain can be divided evenly into the number of holes on the direct indexing plate. For example, to divide the work into 30° divisions, divide 360° by 30. The quotient 12 indicates that you must divide the work into 12 divisions that are 30° apart. Now divide 24 (the number of holes on the direct index plate) by 12 (the number of divisions). The quotient (2) indicates the number of holes that you use to index 30° on the direct index plate.

When you must divide the work into degrees by plain indexing, remember that one turn of the index crank rotates the work 1/40 of a revolution. Since 1 revolution of the work equals 360°, one turn of the index crank revolves the work 1/40 of 360°, or 9°. Therefore, 1/9 of a turn of the index crank revolves or indexes the work 1°. When you select the dividing head index plate for degree indexing a workpiece, 2 holes in an 18-hole circle index the work 1°; 1 hole in a 27-hole circle indexes 1/3°; 6 holes in a 54-hole circle indexes 1°; 3 holes in a 54-hole circle indexes 1/2°; and 2 holes in a 54-hole circle indexes 1/3°. To determine the number of turns and parts of a turn of the index crank needed to index the work for the desired number of degrees, divide the number of degrees to be indexed by 9. The quotient represents the number of complete turns and fraction of a turn that the index crank should rotate. The sector arms are set for the number of holes that give the desired fraction of a turn. The calculation for indexing work 15° using an index plate with a 54-hole circle is as follows:

$$15/9 = 1\ 6/9 = 1\ 36/54$$

or one complete turn of the index crank and 36 holes in a 54-hole circle. The calculation for indexing work 13 1/2° using the 18-hole circle of an index plate is as follows:

$$\frac{13\ 1/2}{9} \times \frac{2}{2} = 27/18 = 1\ 9/18$$

or 1 complete turn and 9 holes in an 18-hole circle. We multiplied both parts of the fraction by 2 to get rid of the fraction in the numerator. If the fraction had been 1/3, we would have multiplied both numerator and denominator by 3; etc.

Wide range. You use wide range indexing to obtain divisions that you cannot obtain by using simpler indexing methods. A wide range index head has two index plates and two index cranks. The small index crank is geared so that 160 revolutions is equal to 1 revolution of the large index crank. It requires 40 revolutions of the large index crank to rotate the work one full turn; therefore, one complete turn of the large crank equals 40 divisions. If a 100-hole circle is used,

1 hole on the large index plate equals $\frac{1}{4,000}$ revolution. If a 100 hole circle is also used with the small index crank, 1 hole on this plate equals $\frac{1}{400,000}$ revolution of the work.

You determine the number of turns of the large and small index cranks by dividing 400,000 by the number of divisions desired. The first two digits of the quotient indicate the number of holes on the large index plate and the next two digits equal the number of holes on the small index plate, if you are using 100-hole circles for both of them. If fewer than 40 divisions are indexed, a five-digit quotient will result. The first digit of a five-digit quotient equals the number of full revolutions of the large index crank. If a fraction remains after the division, divide 1 by the fraction and add one hole to the indexing movement of the small crank at intervals equal to the whole number nearest the result of the division. You will not be able to compensate entirely for the remaining fraction, but the error resulting from one hole on a 100-hole circle on the small index plate is only 0.0000942 inch on a 12-inch diameter. The following example will help you understand how to perform wide range indexing. How would you index 67 divisions, using wide range indexing?

Dividing 400,000 by 67 gives 5,970 1/67. Therefore, for each division, move the large index crank 59 holes in a 100-hole circle and the small index crank 70 holes in the same direction. Compensate for the fraction (1/67) by moving the small index card 1 additional hole (total of 71 holes) when indexing the 67th division. This is a result of dividing 1 by the remainder 1/67, which gives 67 as the nearest hole number.

Compound. When a wide range index head is not available, a method called compound indexing can be used on a plain index head to obtain a wider range of divisions. In compound indexing, the crank is moved a specific number of holes in the regular way on a certain hole circle, and then the index *plate* is revolved a specific number of holes either in the same or opposite direction (depending on the number of divisions), using a different hole circle. For example, to obtain 69 division, you would rotate the crank clockwise 21 holes in a 23-hole circle and then rotate the index plate 11 holes in the *opposite* direction in a 33-hole circle. However, if you needed to obtain 77 divisions, you would rotate the crank clockwise 9 holes in a 21-hole circle and then rotate the index plate 3 holes in the *same* direction in a 33-hole circle. Machinists' publications, such as the *Machinery's Handbook*, contain instructions for calculating for compound indexing and also contain tables giving the required movements for indexing many divisions that are beyond the range of those that can be obtained by the simple indexing method.

Exercises (409):

1. How is the work normally rotated when you perform direct indexing on the index head?

2. Using plain indexing, how many turns and holes should the crank be turned to index 16 divisions using an 18 hole circle on the index plate?

3. **What enables you to index any number of holes on the index plate without actually counting them each time?**

4. Briefly describe degree indexing.

5. If the *direct* index plate is moved 4 holes on a 24-hole circle, how many degrees does the plate revolve?

6. How many degrees will the work revolve if the index crank is turned 19 complete turns?

7. If a 27-hole circle is available, how many turns and holes are required to index 28 1/3°?

8. How does a wide range index head differ from a plain index head?

9. How many holes should the large and small index cranks be moved to index 108 divisions using the wide range indexing head with 100 hole circles for both large and small index cranks?

10. How does compound indexing differ from plain indexing?

410. Explain key procedures for milling graduations, and compute the turns required in a specific graduation problem.

Milling Graduations. Milling graduations is the process of spacing and cutting divisions on linear or circular work. Graduating can be done on a milling machine with a stationary sharp-pointed tool that scribes the graduations on the work. Another method is to mill the graduations with an angular cutter. The latter method procedues a smoother line because there is less chance for the cutter to burr the work.

Linear graduations. Linear graduating is spacing and cutting divisions in a linear plane or straight line, such as the graduations on a rule, vernier caliper, or height gage. If extreme accuracy is not required, you can do linear graduating on a milling machine by

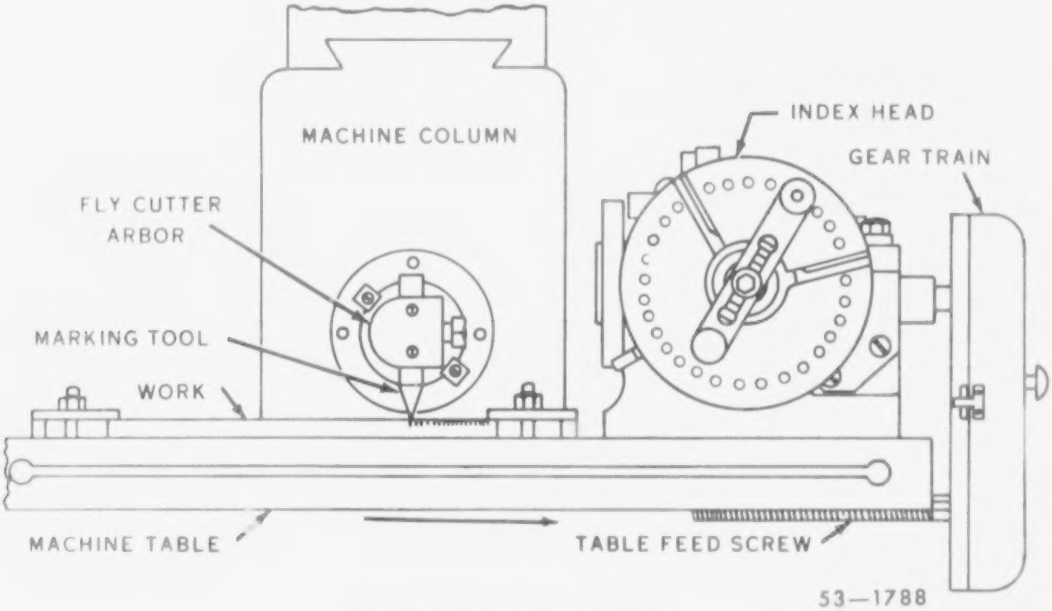


Figure 1-28. Linear graduation setup.

greater accuracy is required, use the dial indicator. Hand feed the tool with the toolslide crank and make the depth of cut by moving the work toward the cutting tool. You can use the crossfeed dial graduations to determine the exact depth of cut. Tilt the top of the clapper box away from the surface being machined, as shown in figure 2-18. You can use a roundnose tool for both the roughing and the finishing cuts when average finishes are permitted. Use side-finishing tools when finer finishes are needed and when you are facing deep vertical surfaces on shoulders and corners. Use squaring tools to finish the vertical surfaces on shallow shoulders and corners and to finish the sides of deep slots or grooves.

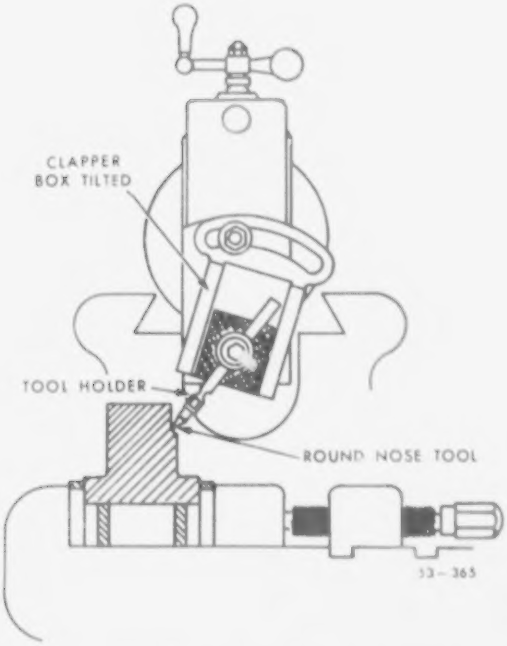


Figure 2-18. Tilting clapper box for down cutting.

If a fine finish is required, first rough the surface with a roundnose tool and leave no more than 1/64-inch for finishing. Then install a side finishing tool and proceed in the following manner. Mount a side finishing tool in a straight toolholder. The toolholder should be positioned in the toolpost so that the 1/16 inch portion of the tool's cutting edge (refer to fig. 2-8) is parallel to the surface to be finished. The best way to position the cutting edge is with a machinist's square, as shown in figure 2-19. Set the machine to the proper length of stroke. Reduce the CFS to about 30 feet per minute to protect the small cutting edge. With the tip of the tool touching the bottom surface of the corner or shoulder, set the vertical feed dial at zero. NOTE: Omit this step when you use the side-finishing tool to finish the ends of the work. To plane wide, deep grooves, leave 0.005 inch on the bottom surface for finishing with a squaring tool. Pick up the vertical surface of the work, using a strip of paper. Use vertical cuts to finish the shoulder or end of work to the correct size. Do not exceed a depth of cut of .004 and a feed of .002.

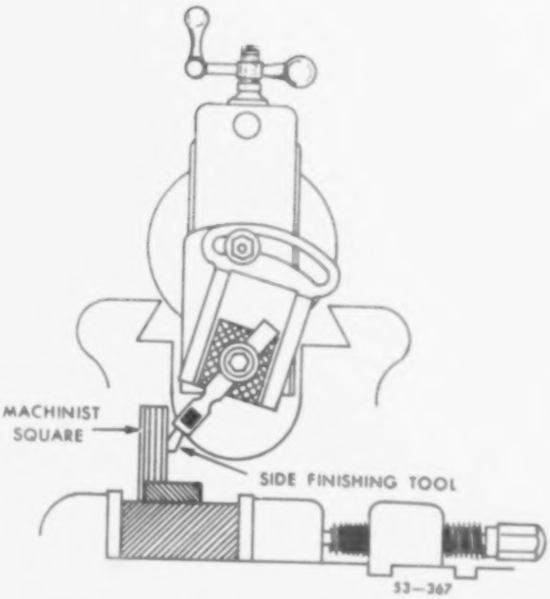


Figure 2-19. Aligning cutting edge with a machinist square.

Exercises (419):

1. How should the toolhead and the clapper box be positioned for vertical planing?

2. What shaper cutting tool is best for finish planing the vertical surfaces of a square groove ½ inch deep and 1 inch wide when an extremely high finish is not required?

3. If a fine finish is needed on a vertical surface, what tool should you use and how should it be set up?

4. When you are planing a very accurate finish on the past part of a vertical next to the bottom of a shoulder, for what rate of feed should you set the power feed?

420. Describe key procedures in machining shoulders and corners.

Shoulders and Corners. Shoulders and corners are machined by removing excess material with a roundnose tool and then finishing with a side-finishing tool or a squaring tool.

You can remove excess material by making a series of horizontal cuts toward the layout line or shoulder. When you are roughing out material between two shoulders, feed the work in both directions. This saves time because you do not have to return the work to a starting point for each cut. When you are roughing between shoulders, the clapper box should be positioned centrally and the toolholder set vertically. Set up the tool as shown in figure 2-20 when you are machining one shoulder. Make each succeeding cut slightly shorter than the preceding cut, leaving a stepped fillet in the corner. Tilt the toolholder to machine closer to the shoulder and to keep the toolholder from interfering with the cut.

The following information will help you understand how a square shoulder, such as the one on the forming die, shown in figure 2-20, is roughed out. Set the toolslide vertically and swing the top of the clapper box slightly away from the shoulder. Mount a roundnose tool in a straight toolholder. Set the machine for the length and position of stroke and the correct speed. Make sure that the ram and toolslide will clear the work and vise. Pick up the cut with a piece of paper and set the toolslide dial to zero. Make the necessary calculations to determine the depth from the top of the work to the bottom layout line. Use a roughing feed. You can use the power feed to machine within ⅛ inch of the layout line and then feed by hand to within 1/32 inch of the line. Move the work back to the starting point of the cut and set the toolslide for an additional depth of cut. Engage the power feed and allow the table to feed until the tool is within ⅛ inch of the shoulder. Feed the work by hand until the tool is within 1/64 inch of the point where the preceding cut stopped. (CAUTION: Be sure that the toolholder clears the work as the depth of the shoulder increases.) Repeat the operations until you obtain the depth you want. NOTE: You can measure the height of the shoulder with a depth micrometer but be sure that you remove all burrs from the shoulder before you make the measurement. Leave approximately 0.005 inch for finishing cuts on the horizontal surface.

Next, position the tool at a 30° to 40° angle with the shoulder to insure that the toolholder does not rub the vertical surface while it is being machined. Pick up the vertical surface of the shoulder and set the crossfed graduated collar at zero. Position the work and the tool bit with the crossfeed and toolslide so that the tool bit contacts the horizontal surface of the work. Then set the toolslide graduated collar at zero. Rough out the stepped material adjacent to the shoulder to within 0.005 inch of the vertical layout line. You do this by making a series of vertical cuts. Use the zero setting of the toolslide and the crossfeed graduated collars as reference points for each cut. Move the work with the table crossfeed for the depth of cut, and move the tool bit downward with the toolslide for the feed. Feed the tool downward to the zero setting on the toolslide graduated collar. This will allow the same amount of material for finishing as was left during the first step.

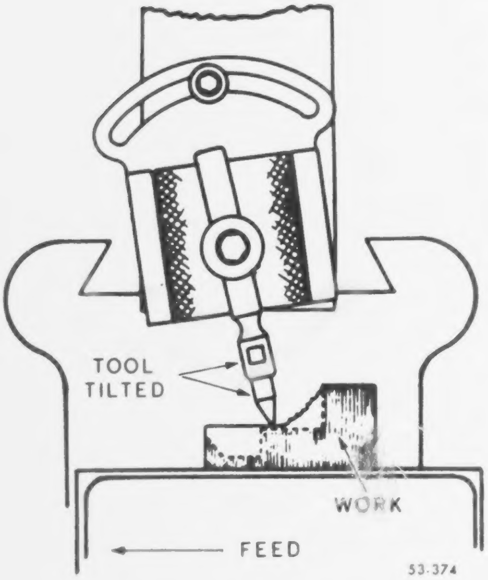


Figure 2-20. Roughing excess to one shoulder.

You have now machined both the vertical and horizontal surfaces to within 0.005 inch of the layout line. If the fillet, or corner, formed by the nose radius on the tool bit is not objectionable and the finish produced by the roundnose tool is acceptable, you can machine the shoulder to the finished dimensions. If you need a better finish and a square corner, you can machine the vertical surface with a side finishing tool or both the vertical and horizontal surfaces with a squaring tool. You obtain the best finish when you use both the side-finishing tool and the squaring tool.

Exercises (420):

1. When you rough machine material between two shoulders with a roundnose tool, how should the clapper box and toolholder be positioned?

2. You are rough machining material to a shoulder with a roundnose tool. At what distance should you stop the power feed and begin hand feeding toward the shoulder layout line?

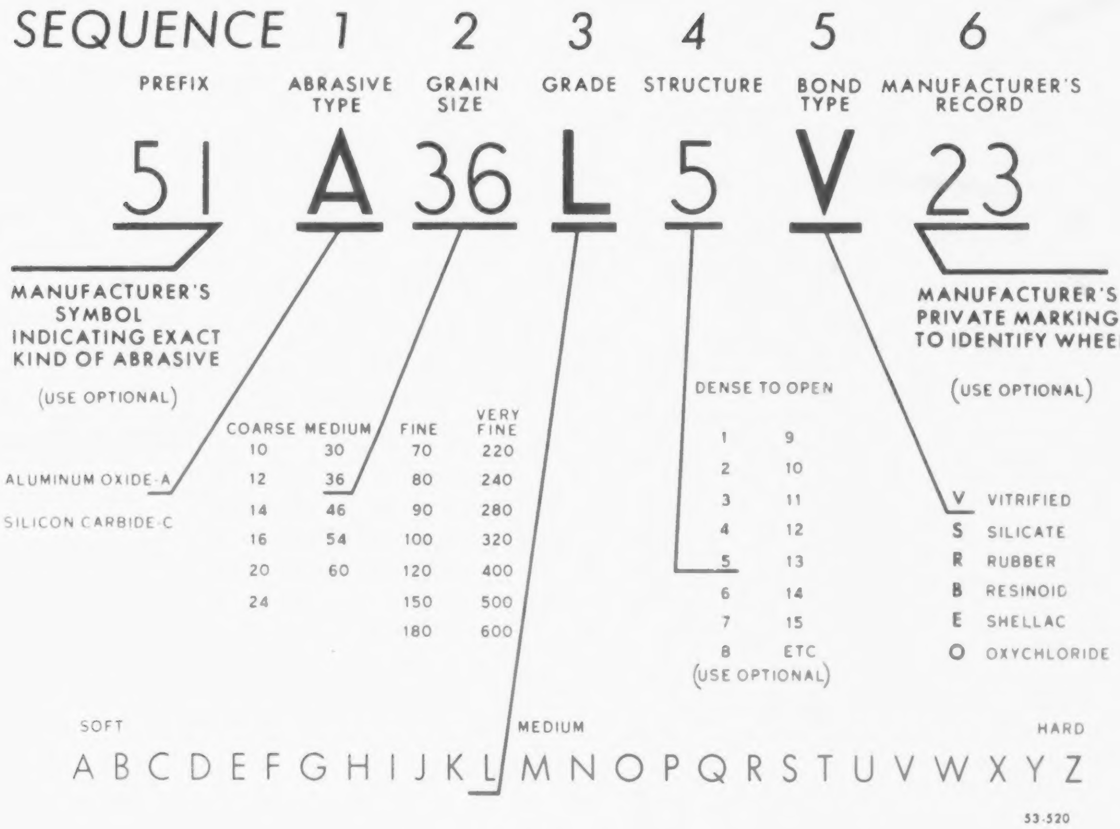

SEQUENCE 1 2 3 4 5 6
PREFIX
ABRASIVE TYPE
GRAIN SIZE
GRADE
STRUCTURE
BOND TYPE
MANUFACTURER'S RECORD
51 A 36 L 5 V 23
MANUFACTURER'S SYMBOL INDICATING EXACT KIND OF ABRASIVE
(USE OPTIONAL)
MANUFACTURER'S PRIVATE MARKING TO IDENTIFY WHEEL
(USE OPTIONAL)
ALUMINUM OXIDE-A
SILICON CARBIDE-C
COARSE
10
12
14
16
20
24
MEDIUM
30
36
46
54
60
FINE
70
80
90
100
120
150
180
VERY FINE
220
240
280
320
400
500
600
DENSE TO OPEN
1 9
2 10
3 11
4 12
5 13
6 14
7 15
8 ETC
(USE OPTIONAL)
V VITRIFIED
S SILICATE
R RUBBER
B RESINOID
E SHELLAC
O OXYCHLORIDE
SOFT
MEDIUM
HARD
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
53-520

Figure 3-1. Grinding wheel markings.

427. Point out the factors that influence the selection of a grinding wheel and explain selected inspection and balancing procedures.

Selection. There are so many different grinding wheels available that it is possible to use exactly the right wheel for each job you do. However, that isn't practical, because you would have to have hundreds of grinding wheels on hand in the shop. Most Air Force shops are small and must rely on a dozen or so general-purpose wheels for grinding operations. For that reason, you must consider several factors when selecting a grinding wheel: the kind of material to be ground, the amount of stock to be removed, the accuracy and finish required, the area of contact between the wheel and the work, the nature of the operation, and the work and wheel speed.

The type of material to be ground usually determines whether you use a silicon carbide or an aluminum oxide abrasive. As we stated before, aluminum oxide is suitable for grinding most steels including high-speed steels, and silicon carbide is best suited for grinding cemented carbide tools and extremely hard alloys.

In choosing the proper grain size, consider both the material to be ground, the amount of stock to be removed, and the area of contact. Fine grain sizes are best suited for hard and brittle materials; but if fast cutting rather than a fine finish is desired, a coarser grain is better. Also, the heavier the cut (which increases the area of contact as shown in fig. 3-2), the coarser the grain size should be.

The grade of the wheel that you choose depends on nearly all of the factors. Generally, hard wheels are used on soft materials and soft wheels are used on hard materials. However, as the size of the area of contact increases, the softer the wheel should be. Also, the higher the surface feet per minute (sfpm), the harder the wheel should be.

Structure also depends on several factors. Generally, dense (or close spacing) structures should be used on hard and brittle materials, and open (or wide spacing) should be used on soft ductile materials. A notable exception to this rule is cemented carbides. Even though they represent one of the hardest known materials, they require wheels with an open structure. Wider spacing is better for rapid stock removal, whereas closer spacing produces a finer finish. Also, as the area of contact increases, so should the spacing.

Bond selection is usually not much of a problem. Vitrified bond is suitable for nearly any type of grinding that you may encounter in an Air Force shop. As we stated previously, there is one big exception; thin, cutoff wheels should have a rubber or resinoid bond.

The nature of the work usually dictates the shape of the wheel you will use. For instance, a straight wheel is commonly used for straight cylindrical grinding and a flaring cup wheel is used for sharpening certain types of cutters and reamers. Figure 3-3 shows the standard grinding wheel shapes.

Inspection. When you receive a wheel in the shop or remove it from storage, you should inspect it closely for damage and cracks. Check a small wheel by suspending it on one finger or with a piece of string. Tap it gently with a light nonmetallic instrument, such as the handle of a screwdriver, as shown in figure 3-4. Check a larger wheel by striking it with a wooden mallet. If the wheel does not emit a clear ring, examine it for cracks, and discard the wheel if it is cracked. All wheels do not produce the same tone when they are rung. A low tone does not necessarily indicate a cracked wheel. Wheels are often filled with various resins and greases to modify their cutting action, and resin or grease deadens the tone. Vitrified and silicate wheels emit a clear metallic ring. Resinoid-, rubber-, and shellac-bonded wheels emit a tone that is less clear. You can readily identify the sound of a cracked wheel.

Balancing. A grinding wheel under 12 inches in diameter seldom needs balancing. Larger wheels, especially those that are to be used in precision grinding, must be balanced. To balance a wheel, you mount it on an arbor and let it slowly revolve on a balancing stand, as shown in figure 3-5. The wheel will come to rest with the heaviest part down. You balance the wheel by shifting the position of the weights, either two or four in number, in a circular groove cut in the

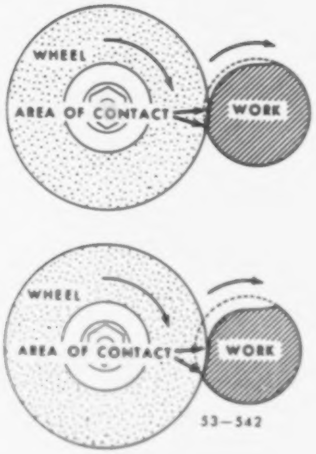


Figure 3-2. Area of contact.

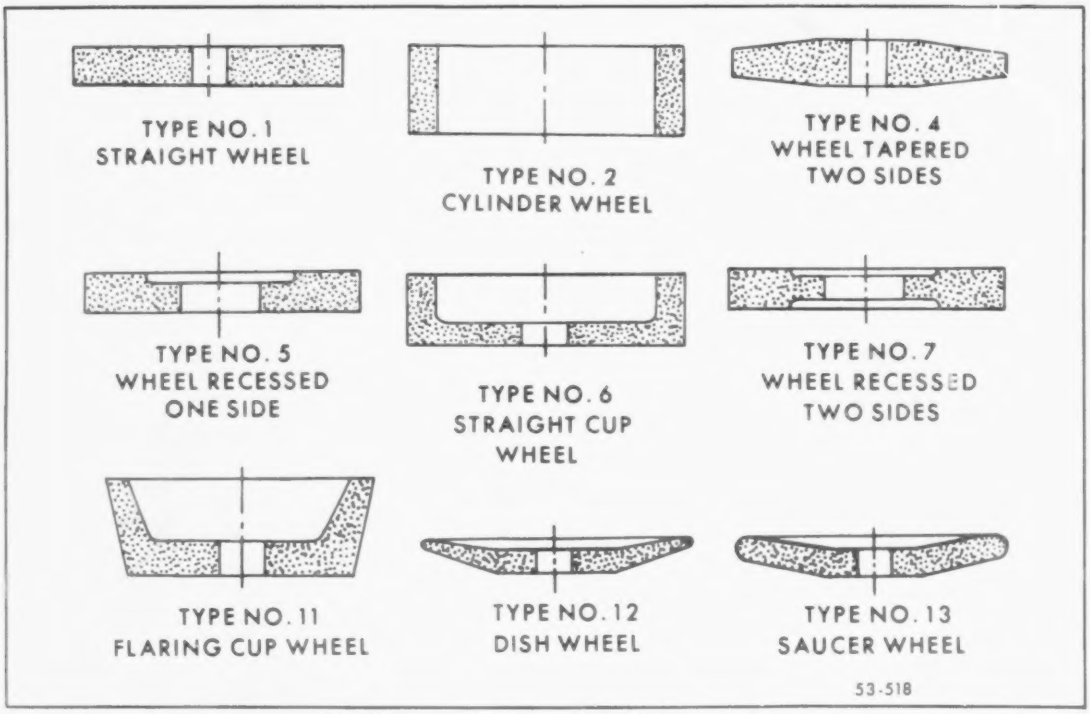

TYPE NO. 1
STRAIGHT WHEEL
TYPE NO. 2
CYLINDER WHEEL
TYPE NO. 4
WHEEL TAPERED
TWO SIDES
TYPE NO. 5
WHEEL RECESSED
ONE SIDE
TYPE NO. 6
STRAIGHT CUP
WHEEL
TYPE NO. 7
WHEEL RECESSED
TWO SIDES
TYPE NO. 11
FLARING CUP WHEEL
TYPE NO. 12
DISH WHEEL
TYPE NO. 13
SAUCER WHEEL
53-518

Figure 3-3. Standard grinding wheel shapes.

wheel mount bushing, as shown in figure 3-6. The weights are secured by a jam screw. If a wheel does not have weights, you can balance it by carefully chiseling out some of the wheel next to the bushing and filling the space with lead. After mounting the wheel, recheck the balance with the wheel rotating. Do not permit a wheel with which you perform wet grinding to remain stationary with a portion of the wheel immersed in the coolant. The wheel will absorb coolant in one area and be thrown out of balance. Also, for the same reason, do not permit coolant to flow on a stationary wheel. After mounting a wheel, stand to one side and let it run at full operating speed for at least 1 minute before using it.

NOTE: A wheel can fly apart. ALWAYS wear eye protection when you are grinding and stand to one side to avoid possible injury. Your eyesight is not expendable!

Exercises (427):

1. What factor usually determines whether you should use a silicon carbide wheel or an aluminum oxide wheel?

2. What two factors normally require you to choose a softer wheel?

3. What type of grinding operation always requires a bond *other than* vitrified?

4. How should you check a grinding wheel for cracks?

5. If a grinding wheel mount bushing does not have weights for balancing, how can you balance it?

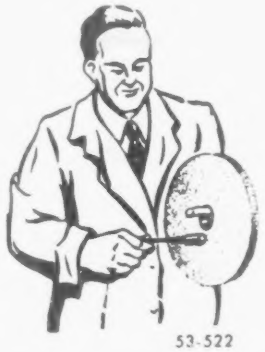


Figure 3-4. Checking for cracks.

428. Explain specified steps in wheel mounting, dressing, and truing.

Mounting. You mount a grinding wheel on the wheel head spindle by means of wheel flanges or a collet. Power is transmitted through the flanges or collet to the wheel. Figure 3-7 shows a flange mounting and figure 3-8 shows a collet mounting.

In flange mounting, you mount the grinding wheel directly on the wheel-head spindle. A flange must be mounted on each side of the wheel. These flanges must be equal in diameter, and the center portion must be relieved, as illustrated in figure 3-7. Only the outer portion of the flanges should exert pressure on the wheel. A paper blotter (no more 0.025 inch thick) or a compressable washer must be inserted between each flange and the wheel. This helps to equalize the clamping pressure of the flanges and prevents damage to the wheel. Paper blotters of the proper size are usually included with the wheel by the manufacturer. However, you should make sure that the diameter of the blotter is large enough to cover the entire area of contact between the flanges and the wheel. The diameter of the flanges should be about one-third of the diameter of the wheel. Some flanges are keyed to the spindle shaft and others are pressed on the shaft. In either case, after the wheel and flanges have been installed, you must prevent the spindle from turning while you tighten the spindle nut against the outer flange. Tighten it just enough to hold the wheel firmly; too much pressure will set up stresses within the wheel which could cause it to explode during operation.

Some grinding wheels are designed for mounting on a collet, as shown in figure 3-8. Small screws that pass through the bore of this type of wheel tighten the flanges of the collet against the wheel. After you have checked the blotters between the wheel and flanges to be sure they are the proper diameter, tighten one screw and then the one directly opposite, etc., to equalize the pressure against the wheel. The wheel can be mounted on the collet with the collet either on or off the spindle. However, if you choose to remove the collet from the spindle, you will usually need a puller. Therefore, it is usually easier to install the wheel without removing the collet from the spindel.

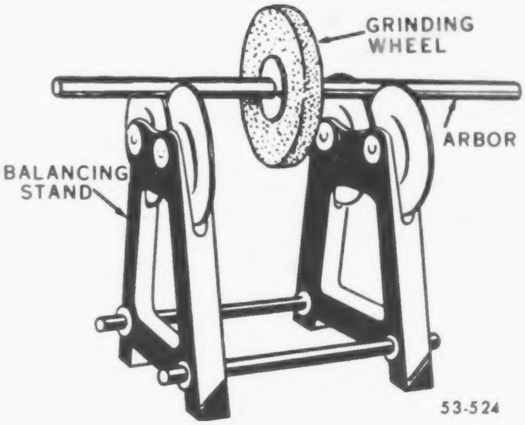


Figure 3-5. Wheel balancing stands.

Dressing and Truing. As you may remember from Volume 2, a grinding wheel is *dressed* to improve or alter the cutting action of the wheel. The wheel is *trued* to restore a concentric surface to the wheel cutting face. You can expect a grinding wheel to perform efficiently only if it is properly dressed and trued. Within limits, a grinding wheel is self-sharpening. The forces acting at the point of contact tend to fracture

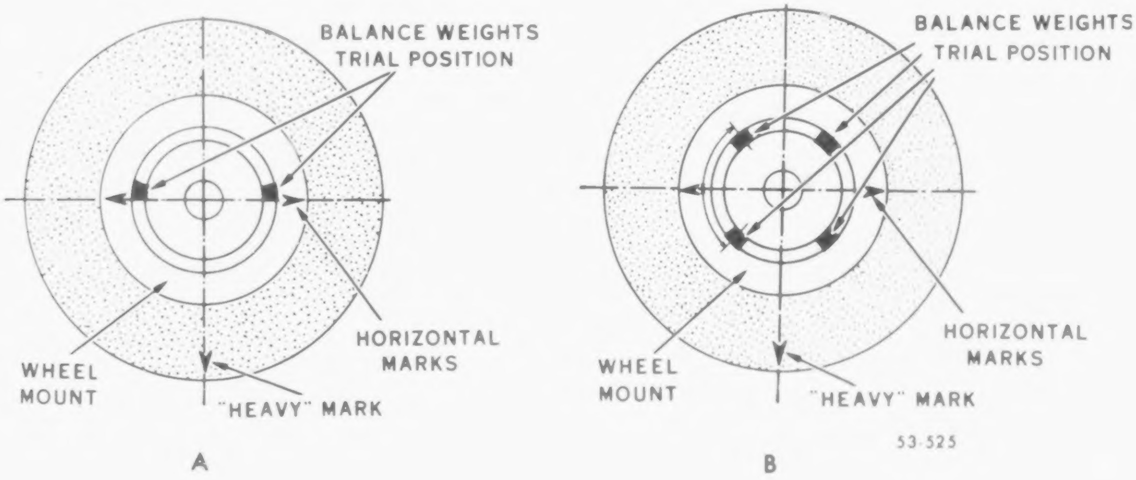


Figure 3-6. Use of balance weights.

and dislodge the dulled abrasive grains. This action results in new and sharp cutting grains contacting the work. In time, however, a grinding wheel needs dressing in order to clean out the metal-clogged pores. There are several types of dressing and truing tools, shown in figure 3-9.

Mechanical dresser. The hand-held Huntington mechanical dresser has alternate pointed and solid discs, which are loosely mounted on a pin. Use this dresser to dress coarse-grit wheels and wheels used in hand grinding. This type is the most efficient in picking the metal particles out of the wheel without causing a big loss of abrasive. You do not need to use a coolant.

Abrasive stick dresser. The abrasive stick dresser comes in two shapes: square, for hand use, and round, for mechanical use. It is often used instead of the more expensive diamond dresser for dressing shaped and form wheels. It is also used for general grinding wheel dressing.

Abrasive wheel dresser. The abrasive wheel dresser is a bonded silicon carbide wheel that is fastened to the machine table at a slight angle to the grinding wheel and driven by contact with the wheel. The dresser produces a smooth, clean-cutting face that leaves no dressing marks on the work. You do not usually need to use a coolant.

Diamond dresser. The diamond dresser is the most efficient for truing wheels used for precision grinding where accuracy and high finish are required. A dresser may have a single diamond or multiple diamonds mounted in the end of a round steel shank. Inspect the diamond point frequently for wear. It is the only usuable part of the diamond, and if it is worn away, it cannot dress the wheel properly. You should slant the diamond 3° to 15° in the direction of rotation, as shown in figure 3-9 (insert), to prevent chatter and gouging. Rotate the diamond slightly in its holder between dressing operations to keep it sharp. A dull diamond presses the wheel cuttings into the bond pores and loads the face of the wheel, which in effect increases the hardness of the wheel.

When you use a diamond dresser to dress or true a grinding wheel, the wheel should be turning at, or slightly less than normal operating speed—*never* at a higher speed. For wet grinding, flood the wheel with coolant when you dress or true it. For dry grinding, the wheel should be dressed dry. The whole dressing operation should simulate the grinding operation as much as possible. Whenever possible, hold the dresser by some mechanical device. It is a good idea to round off wheel edges with a handstone after dressing to prevent chipping the wheel edges. This is especially true of a fine finishing wheel. You do not round off the edges if the work requires sharp corners. The grinding wheel usually wears more on the edges, leaving a high spot towards the center. When you start the dressing or truing operation, be certain that the point of the dressing tool touches the highest spot of the wheel first, to prevent the point from digging in.

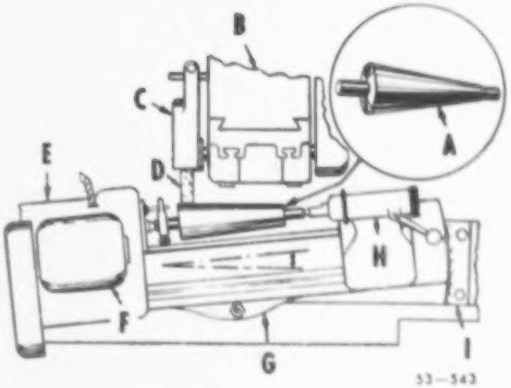
Feed the dresser tool point progressively .001 inch at a time into the wheel, until the sound indicates that the wheel is perfectly true. The rate at which you move the point across the face of the wheel depends upon the grain and the grade of the wheel and the finish desired. A slow feed gives the wheel a fine finish, but if the feed is too slow, the wheel may glaze. A fast feed makes the wheel free cutting, but if the feed is too fast, you may leave dresser toolmarks on the wheel. You can determine the correct feed only by trial, but always maintain a *uniform* rate of feed during any one pass.

5. After checking a grinding project between cuts, you find that there is a 0.0025 TPI in it. You therefore mount a dial indicator so that its spindle contacts the table 15 inches from the table swivel point. How much should you swivel the table to remove the taper?

6. What is the big difference between grinding procedures for grinding the reamer shank and those for grinding the flutes? Why?

432. Name some of the applications of conical taper grinding and internal grinding, and give some of the procedures and problems in these operations.

Taper Grinding. Taper or conical grinding applies to the grinding of round tapered surfaces, such as the shank and the point of a lathe center or the tapered portion of a taper plug gage. The reason that we refer to the operation as conical and not taper grinding is that flat work can also be ground with a taper. You can grind either external or internal work conically to any length.



A	Work	E	Headstock
B	Wheelhead	F	Motor
C	Wheel guard	G	Swivel table
D	Grinding wheel	H	Tailstock
		I	Taper scale

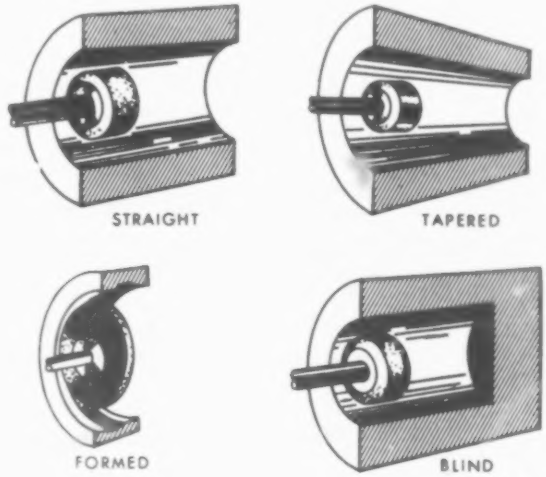
Figure 3-12. Conical grinding setup.

You grind conical tapered work in a manner similar to the grinding of straight cylindrical work provided that the taper is not too steep or abrupt. After placing the work between the centers of the grinding machine, swivel the table to the required taper by means of the graduations on the end of the table. The correct work setup is illustrated in figure 3-12. This setup locates the axis of the work at an angle with the line of motion of the table. As the work moves across the face of the wheel, a taper is ground. The angle or taper depends upon how far you swivel the table from its central position. The correct angle or taper also depends directly upon the relation of the wheel to the work. In lathe work you will remember that, in order to turn a true taper, you must set the cutting tool exactly at center height or even with the axis of the work being machined. The grinding wheel axis must also be exactly at center height or even with the axis of the work to grind a conical taper. If you position the wheel above or below the center of the work, the taper will be different from the table setting indication. When you grind conical tapers, you can dress and true the grinding wheel either before or after swiveling the table. The face of the wheel is always true and parallel to the ways regardless of the angle to which you swivel the table.

Since the table on a universal grinder is limited as to the degree that it can be swiveled, steep conical tapers are normally ground by swiveling the headstock to the desired angle of taper, as shown in figure 3-13. Again, you must be sure that the axis of the grinding wheel is exactly at center height with the axis of the work.

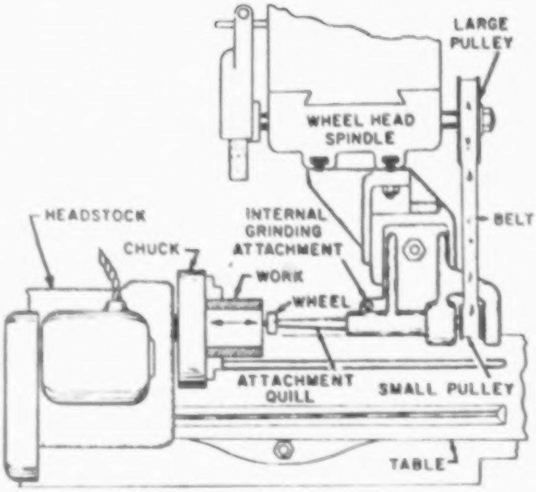
There are several methods of checking conical tapers. The two most common methods are to measure the taper per inch with a micrometer or to check it with a tapered ring gage. When the micrometer is used, you normally make two measurements 1 inch apart. The difference between the two measurements is the taper per inch. This method will not be accurate if the space between the two measurements is not exactly 1 inch. Therefore, it is normally better if you can scribe a line at each measurement point to help in aligning the micrometer.

When a conical taper is to be checked with a tapered ring gage, you should coat either the internal surface of the ring gage or the external surface of the taper with bluing or chalk. Then slip the ring gage over the taper and rotate it slowly. If the taper is correct, the bluing or chalk will rub off evenly. If it rubs off unevenly, it will show where the taper is off and will indicate what machine adjustments must be made to correct it. A disadvantage of using a ring gage is that if the taper is not accurate, you cannot tell exactly how much of an error to correct for. A sine bar and gage blocks used on a surface plate will provide a more accurate way of checking a conical taper. Machinists publications, such as the *Machinery's Handbook*, give tables to help determine the correct setting for a given angle.



53—548

Figure 3-14. Typical internally ground surfaces.



53150-3-2-51

Figure 3-15. Internal grinding attachment.

Internal Grinding. Internal grinding is grinding internal circular surfaces. The applications of this type of grinding are quite extensive. The range of hole sizes and types of work, as shown in figure 3-14, is limited only by the capacity of the machine. Internal grinding is a widely used method of finishing internal surfaces, because it is accurate and economical and produces a good surface. In many instances, this method of grinding has taken the place of reaming and boring holes. You will be called upon many times to finish a hole in a hardened metal part because the heat treating process caused a certain amount of distortion. You must grind the hole internally to secure an accurate diameter and a true surface. Some classes of internal grinding are done on a lathe with a tool post grinder, which we discussed in Volume 2. Internal grinding speeds and feeds are calculated in the same way as external cylindrical grinding.

Internal grinding is done on the universal tool and cutter grinder with the aid of an internal grinding attachment. Figure 3-15 shows a typical internal grinding attachment mounted on a grinding machine. Note that the belt and pulleys are exposed, though, during actual operation, this area should be covered with a guard.

Because small grinding wheels are used for internal grinding, the spindle (or quill as it is called) must be operated at a high speed to maintain the required sfpm. You increase the rpm by placing a large pulley on the machine wheelhead and a small pulley on the attachment. The usual ratio between the two pulleys is 3 to 1.

Most internal attachments come with several sizes of spindles (quills). Use the largest quill possible for the hole that you are grinding. The smaller quills tend to spring away from the work easily and produce taper and irregularities.

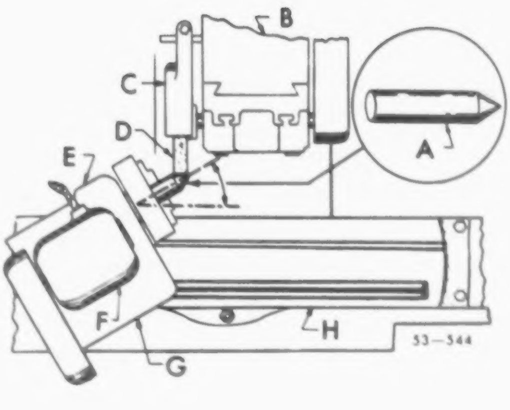
One condition that is more pronounced in internal grinding than in external is the larger area of contact. Large areas of contact usually cause the wheel to load and glaze quickly, which in turn causes vibration and produces poor surface finishes. Therefore, it is important to pay particular attention to the condition of the wheel during the grinding operation. Because of the tendency of the wheel to load in internal grinding it is best to use either a coarser grain wheel to provide more chip clearance or a softer grade wheel that will break down more easily.

During the grinding operation, let the grinding wheel run out of the end of the hole for at least one-half the width of the wheel face but not more than two-thirds. If the wheel is allowed to clear the work each time the table reciprocates, it will grind a bell-mouthed hole because of spring in the quill.

You can also grind internal conical tapers on a universal grinding machine. A combination of the rules for external conical grinding and those for straight internal grinding applies when grinding internal conical tapers. The main thing to remember is to be sure that the axis of the quill is at center height with the axis of the work. Internal conical tapers are normally checked with the mating part or with a tapered plug gage.

Exercises (432):

1. Name some of the applications of conical taper grinding.



A	Work	E	Headstock
B	Wheelhead	F	Motor
C	Wheel guard	G	Swiveled headstock
D	Grinding wheel	H	Table

Figure 3-13. Conical grinding setup for steep tapers.

2. How should the work be aligned for grinding a long taper between centers?

3. If you were grinding a long conical taper between centers and, even though the table was swiveled the correct amount, the TPI is still not right, what is the probable cause of the trouble?

4. How can you grind steep tapers on a universal grinding machine?

according to table movement. On the reciprocating table type, you mount the work on a reciprocating table, which passes the work back and forth under the wheel face. Wheel feed takes place at each end of the table movement. The depth of cut is normally obtained by feeding the wheelhead down into the work. Figure 3-19 illustrates surface grinding on a reciprocating table. On a rotating table type, you mount the work on a circular table, which rotates the work under the wheel face, as shown in figure 3-20. The wheel moves in a horizontal plane across the work from the outer to the inner circumference and back. You obtain the depth of cut by moving the table upward into the wheel.

Assume that you must grind two sides of a hardened steel parallel to a specified size on a reciprocating table-type surface grinder. You can perform this operation as follows: Mount the proper wheel on the wheel flange assembly. Mount the wheel and wheel flange assembly on the wheelhead spindle. Tighten the spindle and flange nuts. Place guards over the wheel. Mount the diamond dresser and holder, as shown in figure 3-21, on the magnetic chuck and turn the chuck switch to the ON position. (NOTE: Tilt the diamond in the direction of wheel rotation.) Position the wheel directly over the diamond. Start the wheel rotating and bring the wheel down until it touches the diamond. Turn on the coolant, and dress and true the wheel by using the hand crossfeed. Move the wheelhead assembly away from the table enough to allow safe and easy access to the chuck face. Position the magnetic chuch switch to the OFF position and remove the diamond and holder from the chuck. NOTE: Avoid sliding the part across the chuck face. Tip it slightly sideways and pick it up.

Clean the chuck face thoroughly to remove all abrasive residue. Place the parallel on the magnetic chuck, and shim if necessary. Turn the magnetic chuck switch to the ON position. Position the longitudinal trip dogs so that the wheel will run off the parallel at both ends. Position the transverse trip dogs so that the wheel will run off the sides of the parallel. Turn on the machine, the hydraulic system, and the coolant pump. Check the power feed and the wheelhead and table for wheel overrun and make any necessary adjustments. You can use the continuous power feed for these settings. Using the hand feed, position the wheel directly over the parallel and pick up the cut while the table is in motion. Position the coolant nozzle to supply an adequate volume of coolant to the wheel and the parallel.

Turn on the power feed and rough grind the first side of the parallel. The depth of cut should not exceed 0.002 inch. After the first side is rough ground, stop the table motion and move the wheelhead assembly away to allow safe access to the parallel. Turn the magnetic chuck switch to the OFF position and remove the parallel. Clean the chuck thoroughly. Replace the parallel in the same position on the chuck with the ground side down. Turn the magnetic chuck ON and rough grind the second side to within 0.003 inch of the specified size. Next, prepare the machine for finish grinding by redressing the grinding wheel and slowing the power feed setting. When you finish grind the parallel, the depth of cut should not exceed 0.0005 inch. Grind approximately 0.0015 inch off the first side and then finish. Grind the second side down to the exact specified size. Deburr the parallel with a honing stone to remove the rough edges and check all dimensions for accuracy.

Exercises (434):

1. Briefly describe the two types of horizontal spindle surface grinders.

2. Explain the procedure for dressing the grinding wheel on a reciprocating table surface grinder.

3. How should you determine where to place the table trip dogs when you are surface grinding a parallel?

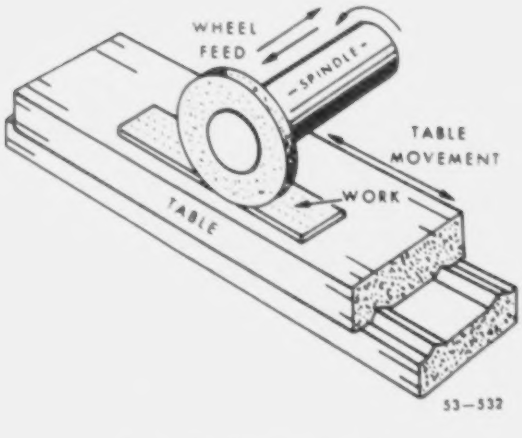


Figure 3-19. Reciprocating table.

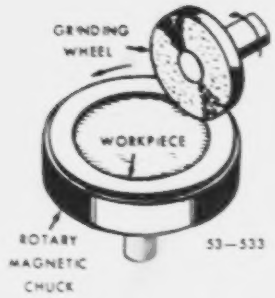


Figure 3-20. Rotating table.

4. Explain the procedure for picking up the cut when you are preparing to grind a parallel on the surface grinder.

5. State the limits for the depth of cut for rough grinding on the surface grinder. For finish grinding.

3-5. Tool Sharpening Operations

The working efficiency of a cutter is determined largely by the keenness of its cutting edge. Therefore, it is important to sharpen a cutter at the first sign of dullness. A dull cutter not only leaves a poorly finished surface, but after its continued use, you have to grind away a large portion of the teeth to restore the cutting edge. If you maintain a cutter in good working condition by frequent sharpening, it always cuts rapidly and effectively. When such a cutter does need sharpening, you have to grind the teeth only a very small amount to insure a keen cutting edge. In this section we will discuss grinding cutters cylindrically, cutting tool clearance, grinding form cutters, grinding shell end mills, and grinding helical milling cutters.

435. State the purpose of grinding cutting tools cylindrically and point out some precautions to observe.

Grinding Cutters Cylindrically. Certain types of cutting tools, such as reamers and milling cutters, are ground cylindrically to remove warpage from heat treatment, to remove nicks, to obtain a specific diameter, or to produce a finish and a slight clearance on the cutting edges of the teeth. When you grind tools cylindrically, the work is rotated in the opposite direction from that ordinarily used in cylindrical grinding. If a clearance is desirable on the cutting edges, the wheel and the work should move in the same direction at the area of contact, as shown in figure 3-22. Mount the cutter so that the heel of the tooth strikes the

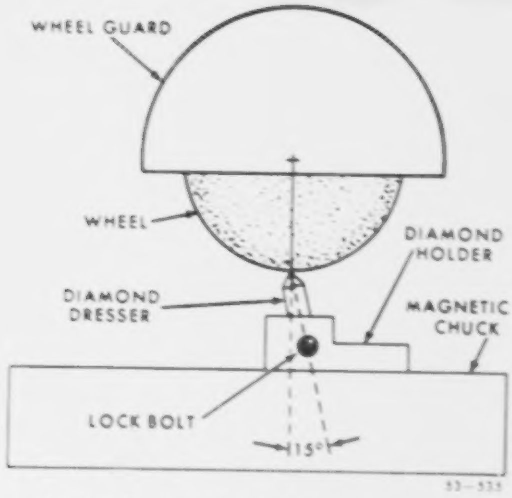


Figure 3-21. Surface grinder wheel dressing setup.

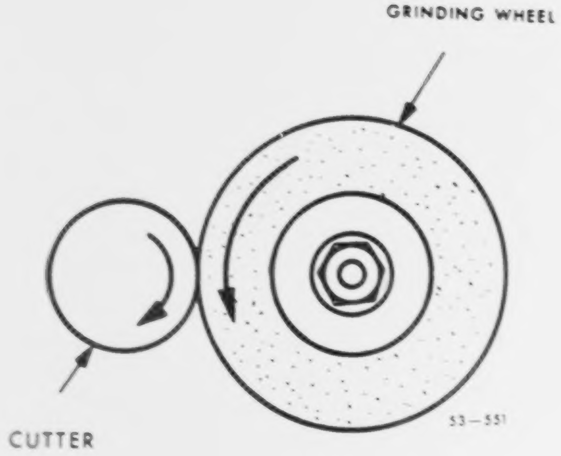


Figure 3-22. Wheel and cutter rotation for cylindrical grinding.

wheel first. In theory, this will cause a slight spring between the work and the wheel, which in turn will cause the heel of the tooth to be ground slightly lower than the cutting edge. The clearance will vary in amount, depending upon the rigidity of the cutting tool being ground and the work setup. The work can be held for the cylindrical grinding operation in three ways: between centers, on a mandrel, or on a stub arbor mounted in the headstock spindle. You should normally select a medium grain and a medium grade grinding wheel for the cylindrical grinding of hardened steel and high-speed steel cutters.

After you have cylindrically ground a cutter or reamer to restore concentricity, you can use either of two methods to sharpen the cutting edges of the teeth and to provide extra clearance. These methods depend upon the rotation of the grinding wheel in relation to the cutting edge. Figure 3-23 illustrates these two methods of straight grinding wheel setup. In method A, the rotation is from the body of the tooth off the cutting edge. The wheel rotation holds the cutter on the tooth rest but will raise a burr on the cutting edge, which you must remove by stoning. This method has a tendency to draw the temper from the metal. In method B, the wheel rotation is from the cutting edge toward the body of the tooth. In this method, there is less danger of burning the tooth, but you must exercise great care in holding the cutter on the tooth rest. If the cutter turns while you are grinding the tooth, it will be ruined. Cup wheels, shown in figure 3-24, are also used extensively to grind cutters and reamers. You use cup wheels very much like straight wheels.

Exercises (435):

1. What is the purpose of cylindrically grinding milling cutters?

CHANGES FOR THE TEXT: VOLUME 4

Pen-and-Ink Changes:
In the following locations change "AFM" to "AFR":

Page-Col	*Subject*	*Lines*	*Correction*
36R		12 fr bot	
45L		9	
52L		17 fr bot, 28 fr bot	
52R		13	
57R		3	
64R		4 fr bot	
69R		26, 27, 29	
72		10, 11, 14	
75R	631-4	1	
76R	641-7	3	
Front cover			Change "(AFSC 53150)" to "(AFSC 42750)."
2L		15	Delete "face."
4R		1,2, fr bot	Insert comma after "shape" and after "angles."
5L	601-2	1	Change "overloading" to "overlooking."
20L		20	Change "strips" to "stages."
22L		3 fr bot	Change "wire of the proper width of stock." to "stock that is wider than that which would be required to produce a single row of blanks."
23R		4 fr bot	Change "designed" to "designer."
30R		12	Insert comma after "action."
31L	619-4	2	Delete "requiring repair within 45 days." Add "that must be repaired within 45 days or be put out of commission."
33R		2	Delete period and add "only after the appropriate NI&RT lists the TO as rescinded."
34L		25	Change "TO IF-4C-1-FS-1" to "TO 1F-4C-1-SS-1."
34L		26	Change "TO 1F-4C-1-F-2" to "TO IF-4C-1-S-2."
35R		13 fr bot	Add "approximately" between "are" and "90,000."
38L		14	Change "the way they are used in" to "the way they are used and in."
41L		19 fr bot	Change "as well as may have to fit around" to "as well as schedule them around."
41R		29 fr bot	Change "extra personnel in" to "extra personnel to do the job in."
44R		23	Change "are used to select" to "are used to aid in selecting."
44R		30	Change the line to read: "airman on a scale from zero to nine. These areas are titled:"
44R		12 fr bot	Delete "your."
45L		8	Delete "your."
48R		7 fr bot	Change "being" to "begin."

Page-Col.	*Subject*	*Lines*	*Correction*
55R	639-7	1-3	Change to "The demonstration method is most effective when a particular training objective is involved. Give this objective."
56R		1	Change "you can help" to "they can help."
57R		4 fr bot	Change "There must be added to the annotated items on" to "They must be added to the JPG by using."
62L		26	Change "case" to "cases."
63R		17	Change "has" to "had."
65R		4 fr bot	Change "have" to "has."
66L		27	Change "It" to "RPC."
66L		32	Change "RACC" to "RPC."
66R		3	Change "AFTO Form 350" to "AFTO Form 349."
73R	605-2.f		Change "3, 5" to "5,4."
74L	609-2	1	Add ")" after "(three."
74L	612-3	2-3	Change "twice as many pieces as it does on two narrower strips." to read "as many pieces as it does on two narrower strips even though the stock is not as wide as the two narrow strips."
75L	621-6	1	Insert "front of" between "in" and "the."
75R	631-1		Delete "select" and insert "aid in selecting" after "to" and "the."
76R	639-7	1	Change to read "This is the development of manual skills."

Page Changes: Remove old pages and insert new pages as indicated. If the placement pages number more than those they replace, those pages in excess of the pages being replaced will carry letter designations. For example: 20, 20a, 20b, etc.

Remove Pages	*Insert Pages*
iii-iv	*iii-iv*
11-12	11-12
25-26	25-26
49-50	49-50a
59-62	59-62
77-78	77-78

Preface

YOU HAVE MADE IT to the last volume of the Career Development Course. But don't let up yet. This volume contains some very important information that you need to round out your studies in preparation for the award of the 5 level. Chapter 1 examines the techniques of tool design and fabrication. Chapter 2 covers technical publications, and Chapter 3 covers supervision and training. And finally in Chapter 4 we examine the various aspects of maintenance management.

Direct your questions or comments relating to the accuracy or currency of this volume to the course author: Tech Tng Cen/TTGXW; ATTN: SMSgt John D. Wurm, Chanute AFB IL 61868. If you need an immediate response, call the author, AUTOVON 862-2385, between 0800 and 1600 (CST), Monday through Friday. *NOTE: Do not use the suggestion program to submit changes or corrections for this course.*

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to a Successful Course, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If this person can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of July 1981.

Contents

Page

Preface .... *iii*

Chapter

1 Tool Design and Fabrication 1

2 Technical Publications 29

3 Supervision and Training 40

4 Maintenance Management 59

Bibliography 72

Answers for Exercises 73

2. Match each of the jig uses shown in column B with the jig type, found in column A, so used by writing the number beside each use in the space provided before its associated letter-coded jig type. Each item in column B may be used once or not at all.

Column A

______a. Template.
______b. Plate.
______c. Channel.
______d. Angle plate.
______e. Closed or box.
______f. Indexing or rotary.
______g. Combination.

Column B

1. For holding parts with simple symmetrical shapes.
2. For holding parts that must be drilled from more than one direction.
3. For drilling out four parts holding a grease seal.
4. For holding several identical parts at once.
5. For drilling holes that must be located at angles to each other.
6. For locating holes for setscrews on pulleys and gears.
7. For drilling holes in a flat workpiece.
8. For guiding a drill or cutting tool in a diagonal instead of a vertical plane.
9. For accurately locating the drill bit on limited production work.
10. For performing more than one operation on the same hole.

606. Compare the characteristics and applications of the various types of jig bushings and fastening and aligning devices with those bushings and devices and indicate the factor(s) determining the design/shape of such devices.

The various kinds of jig bushings and fastening and aligning devices are important to machinists. That is why they are covered at this point.

Types of Jig Bushings. Jig bushings are made of hardened steel. Since a jig bushing serves as a guide for a drill in locating a hole, the dimensions of the hole in the bushing must be extremely accurate. Standard bushings are available and can be used in production work. However, a jig is often fabricated for limited production. In this situation, you will probably fabricate the bushing as well as the jig. We will discuss the following five main types of bushings: (1) press fit, (2) fixed remewable, (3) slip renewable, (4) screw, and (5) special.

Press fit. Press-fit bushings are permanently pressed into position. Used only for limited production, they are put into simple jigs that are employed for just one machining operation, such as drilling. Two types of press-fit bushings exist: (1) plain and (2) shoulder. Plain bushings can be set closer together than can shoulder bushings. It is better to use them when their location in a jig requires a flush surface or when the holes in the jig plate are closely spaced. However, shoulder bushings are better for general use because there is less danger of their becoming dislodged by the cutting tools.

Fixed renewable. A fixed-renewable bushing fits into an outer sleeve, which is pressed into the jig plate. It is kept in place until it is worn out. Then it is replaced without changing the dimensions of the sleeve in the jig plate.

Slip renewable. The slip-renewable bushing also fits a sleeve. It makes possible the drilling of several holes, because it can be moved from hole to hole. Also, bushings of different sizes can be used in the same sleeve to facilitate drilling, reaming, and boring. This type of bushing must be clamped to keep it from rotating with the drill or cutting tool and from rising from the sleeve. Many ways can be used to clamp a bushing in place, as shown in figure 1-10.

Screw. The screw bushing, shown in figure 1-11, performs well for light work with large tolerances. These bushings not only guide the tool but also clamp the work firmly and eliminate the need for other holding devices. A disadvantage of this type of bushing is that, when the thread becomes worn, it is inaccurate. A screw bushing must have a head that can be turned by a wrench. For the several different types of heads, shown in figure 1-12, you use (from left to right) (1) an end wrench, (2) a round-tipped spanner, (3) a square-tipped spanner, (4) a socket or box end, and (5) a special pin wrench, respectively. In each case, the intended use of the bushing determines the type of head you will select.

Special. Special bushings can be designed and made according to the task they must perform. Here your skill and ingenuity are your only guides. If an operation requires a bushing that is not of a normal configuration—for example, when the holes to be drilled are too close together to use three separate bushings—you must design a single bushing to accommodate the three holes.

Fastening and Aligning Devices. For every type of jig or fixture designed and used in any machine shop, there must be some means of clamping the workpiece to either the jig or the fixture. Also, some provision must be made for alignment. The design of clamping devices is limited only by your imagination. Some of the more common clamps are the screw, cam, hook, wedge, toggle, and rack and pinion. You can use one or all of these in one form or another. The function of

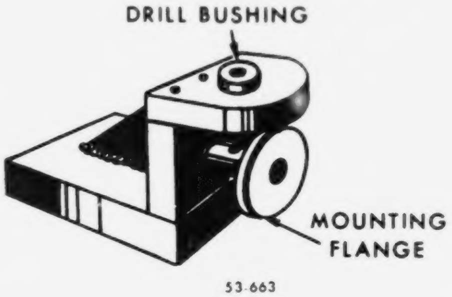


Figure 1-9. Angle plate jig.

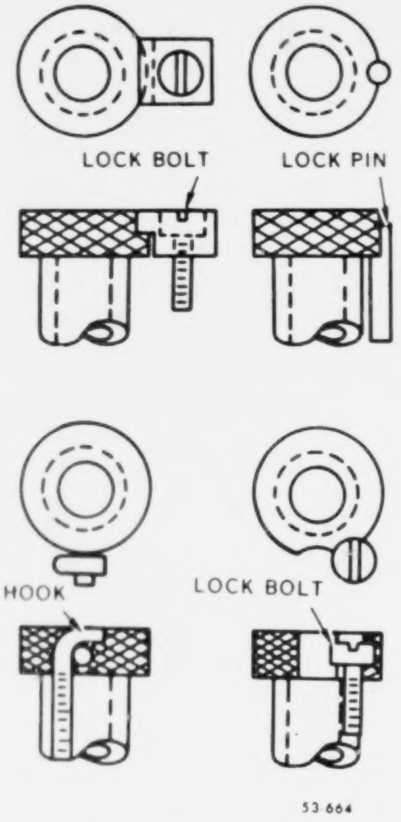


Figure 1-10. Bushing clamps.

the jig will guide you in selecting the type to use for clamping. Aligning devices are many and varied. Here again, the size, shape, and operational need governs the type of aligning device you should use.

Exercises (606):

1. Match each jig bushing characteristic or application shown in column B with its corresponding type of jig bushing, given in column A, by putting each number-coded characteristic or application in the appropriate space beside its associated letter-coded jig bushing. Each type of jig bushing may have one or more than one applicable characteristic or application.

Column A

_____a. Press fit.
_____b. Fixed renewable.
_____c. Slip renewable.
_____d. Screw.
_____e. Special.

Column B

1. Fits into an outer sleeve that is pressed into the jig.
2. Is best suited for light work with large tolerances.
3. Is used mainly in simple jigs that are used for only one machining operation.
4. Shape is designed to fit the task they must perform.
5. Is pressed into an outer sleeve.
6. Must have a head that can be turned with a wrench.
7. Are designed either as plain or as shoulder-type bushings.

2. Tell what governs the design or shape of fastenings and aligning devices.

607. Give the features of selected types of milling fixtures and their uses and, given a typical situation, identify the fixture type most suitable for the job.

Numverous kinds of or classes of fixtures exist and are of concern to us here.

Fixtures. Several classes of fixtures which exist can be subdivided into many types. In each case, however, the class of a fixture is determined by the machine on which it is used. A few examples of the machines on which you use fixtures are the milling machine, planer, lathe, boring mille, and turret lathe. You can also design these fixtures to be used on more than one machine. However, we will limit our discussion here to milling fixtures.

The type of fixture selected depends upon both the kind of milling operation to be performed and the type of cutter used. Milling fixtures aid in the performance of many milling operations. Among these are (1) form milling, (2) angular milling, (3) T-slot cutting, and (4) straddle milling.

Auxiliary vise jaw. One of the simplest and most widely used fixtures is a set of auxiliary vise jaws. These vise jaws are built to replace standard vise jaws and are used for simple milling operations, if the shape and the size of the workpiece permit. But although they are usually made to fit only one part, an exception is the V-block vise jaw. The governing factors of this special vise jaw are the size of the vise and the depth to which the V-block is cut. The auxiliary jaw usually replaces the stationary jaw in the vise, with the movable jaw only holding the part in place. As a usual rule, auxiliary vise jaws are made of

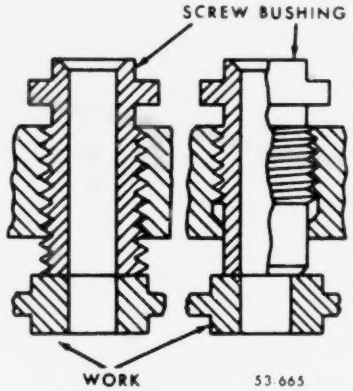


Figure 1-11. Screw bushings.

614. Determine the clearance and relief angle requirements for blanking and piercing die operations and define "land of the die" and give its purpose.

To a machinist, clearance and angular relief must be understood. This segment covers these things.

Clearance and Angular Relief. There must be a definite amount of clearance between the punch and the die for blanking or piercing. The amount of clearance is controlled by the thickness and type of material to be blanked. Thus, for thin material with a low tensile strength, such as brass, for example, the clearance is very small. Yet, if too much clearance is applied, the blank will have ragged or burred edges. In any event, heavy stock needs more clearance than thin stock. The reason why it requires greater clearance is to lessen the possibility of breaking the punch or die and to reduce the pressure required to complete the blanking operation. The clearance is designated by two methods, as follows: The first is to designate the space between the punch and the die on *one side only*, or one-half the total difference between the sizes of the punch and the die. This method of designating die clearance is most useful when you are working with parts of nonsymmetrical forms or irregular contours. The second method is to designate the total difference between the sizes of the punch and die. This method works best and is less confusing in connection with symmetrical parts. In all cases, then, be sure to specify the method of designating clearance that you have used. This will help to eliminate confusion and error.

When the stock is brass or soft steel, the clearance on most dies on one side is equal to 5 or 6 percent of the stock's thickness. For some classes of work, one-half of this clearance is preferred. For some piercing operations, a clearance equal to 10 percent of the stock's thickness gives the cleanest fracture. This clearance may be used in such an operation as punching holes in ductile boiler plate.

If blanks are to pass through a die, as seen in figure 1-33, an angular relief is needed to keep the blank from jamming in the passage. The amount of relief ordinarily given a blanking die varies from 1/4° to 2°. However, dies to be used for a relatively small number of blanks are sometimes given a relief of 4° to 5° to facilitate making the die quickly.

There are two methods of applying angular relief to a die. The first method is to extend the angular relief from the bottom of the die to the top surface or to the cutting edge. This method is best suited for thin, soft materials. The second method is to leave a straight section below the cutting edge of the die. This straight section should be about 1/8 inch in width. The second method is best suited for harder materials. The straight section, called the "land of the die," permits many sharpenings of the die without changing the size of the die cavity.

Exercises (614):

1. State how clearance between the punch and the die is designated.

2. Indicate the clearance normally required for mild steel.

3. Tell where angular relief is required for efficient blanking die operation.

4. Specify how much relief is ordinarily provided for efficient blanking die operation.

5. Define "land of the die."

6. Give the purpose of the "land of the die."

615. Indicate important methods of determining the size of the die block and calculations for determining blanking pressure and resolve hypothetical situations involving those methods and calculations.

At this point, die thickness, length and width and blanking pressure should concern you. These are this part of this volume's topics.

Die Thickness, Length and Width. Some general rules for calculating the thickness of small dies exist which you should know. Thus, for blanks with a perimeter of 3 inches or less, use a die block thickness of at least 3/4 inch. Again, for blanks with a perimeter

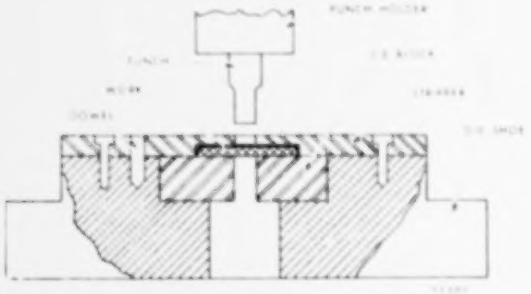


Figure 1-35. Channel-type stripper.

BEST COPY AVAILABLE

of 3 to 10 inches, use at least a 1-inch die block thickness. Also, for blanks with a perimeter of over 10 inches, use at least a 1¼-inch die block thickness. Consider the situation when you have to manufacture a round die to blank a 7/8-inch disk. Here the perimeter of that part is calculated by multiplying pi (P) times the diameter, which is 3.1416 × .875 = 2.7529. As you can see, the, the perimeter is less than 3 inches; so the die block thickness should be 3/4 inch.

Remember, too, that there should be a margin of 1¼ inches around the die opening. Such a margin needs to be left around the die opening in order to insure that the die does not break during the blanking operation. This margin also provides enough material for capscrews and dowel pins. To calculate the length and width of a rectangular or square die, add 2½ inches to the length and to the width of the part to be manufactured. Thus, for example, calculate the length and width of the die block for a die to blank a rectangle that measures 2.375 inch by 4.875 inch as follows: 2.375 + 2.500 = 4.875 inch width, and 4.875 + 2.500 = 7.375 inch length.

Blanking Pressure. Blanking pressure depends upon the material and the area to be sheared, together with the percent of penetration and the amount of shear on the punch. For round holes, the pressure required equals the circumference of the holes times the thicknes of the stock times the shearing strength. The formula is this:

$BP = L \times T \times S$
BP = blanking pressure
L = length of cut in inches
T = thickness of material
S = shear strength of material in psi (pounds per square inch)

To allow some excess pressure, the tensile strength can be substituted for the shearing strength. The tensile strength of common materials is roughly assumed to be as follows: mild steel, 60,000 pounds per square inch; wrought iron, 50,000 pounds; bronze, 40,000 pounds; copper, 30,000 pounds; aluminum, 20,000 pounds; zinc, 10,000 pounds; and tin and lead, 5,000 pounds.

You can reduce the amount of blanking pressure needed to cut a workpiece by as much as 50 percent by placing suitable shear on the punch. Figure 1-36 shows an example of shear applied to a punch. When a shear is placed on a die member, the amount of pressure required to perform the operation is reduced. This result not only reduces the amount of pressure needed but also adds to the life of the punch. If the blank is the workpiece, the shear should be on the die, and the punch should be flat, because the shear angle has a tendency to distort the metal. If the blank is scrap and the strip must be flat, the shear should be on the punch. Shear should be applied to the die member that contacts the scrap. The amount of shear added to the punch or die should be equal to a taper, across the face of the punch or die, of 1½ times the thickness of the stock to be blanked. It may, however, be preferable for you to use a double angle starting at the center of the punch or die. Why? Because this double angle helps maintain symmetry and prevents the setup of lateral forces.

Exercises (615):

1. *Situation:* You must make a die for blanking thin stock. The blank measures 0.825 inch square. State how thick the die block should be.

2. Tell how you can determine the width and length of a die for blanking rectangular pieces.

3. *Situation:* You must punch out some 4-inch diameter disks of cast iron which is 0.125 inch thick. Give the blanking pressure which should be used to allow some excess here.

4. *Situation:* You know that the blank is the scrap. Identify the die member to which you should apply a shear angle.

616. Given a typical situation, specify the method for providing the proper clearance on a punch and die set and cite the techniques for contour sawing dies.

A specialist like you works regularly with clearance problems. The manufacture of die sets involves problems such as determining where to place the required clearance and how to produce this clearance while contour-sawing dies.

Clearance. The application of clearance to the die block of punch is a most important step in the fabrication of dies. Why? Because if clearance is not properly calculated and applied to the proper die members,

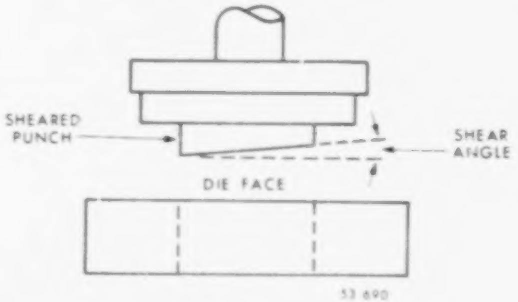


Figure 1-36. Shear applied to punch.

temporary or permanent conditions? Also, check the unit detail listing (UDL) to see how many men are authorized. Remember, the UDL may authorize more people than are assigned at the present time. In any event, if you determine that the mission cannot be supported properly, alert the commander to the problem.

Before personnel and equipment can be justified, it is important to have all necessary information. Accordingly, the commander normally keeps close watch over his manning and equipment authorization. It is possible, however, that you may supply one small fact that may serve as justification for an emergency manpower request or reassignment of work to other sections. The same is true of equipment. Replacement for faulty equipment or that which is in limited supply and hard to repair may be justified. This is why the commander may want to review the facts with you; he wants to insure that he *does* have all of the necessary information clearly in his mind before going to higher commands for help.

Exercises (635):

1. List those conditions that may affect manning and equipment authorization.

2. When a manpower problem is given to the commander, he may use two types of action to solve the immediate problem. List these actions.

3. Tell why the commander wants to review manning and equipment information.

3-2. Conducting Training Programs

An organization capable of doing its job must conduct an endless and effective training program. Every time a piece of equipment is developed, men have to be trained to operate and maintain it. This training is needed if we are to get the greatest use and performance from our equipment. Commanders, personnel officers, training officials, and supervisors must see that this training is conducted as efficiently and as effectively as possible.

Most of the training in the Air Force is conducted on the job. On-the-job training (OJT) is not new. It was used by the cavemen when he taught his sons how to hunt, trap, and make crude weapons. It was used in Europe hundreds of years ago in the craft guild system. It has been used in industry in this country for many years. Today, most companies have well-organized and effective training programs. OJT is a system that works. Obviously, poorly trained workers mean an increase in waste. They also can cause damage to equipment, inefficient operation, lower production, and lower profits. In contrast, well-trained workers mean higher production, good morale, greater profits, and higher wages. Remember, if industry does not train its workers, it loses money; if it loses money, it goes out of business. But the USAF cannot afford to go out of business; so it conducts a training program to keep its personnel qualified to perform all of their duties and functions. This training is necessary if we are to have an efficient, well-manned Air Force capable of carrying out its assigned mission.

636. Give the requirements of an effective OJT program, reasons for setting up this program, the meaning of dual-channel concept, and the document controlling CDC content and the role of CDCs in UGT; explain QT briefly; and given an OJT situation, tell why the supervisor failed.

As a machinist-supervisor, you need to understand On-the-Job (OJT) training thoroughly, because you will be dealing with it. This is our subject here.

The OJT Program. To be effective, an OJT program requires detailed planning, careful scheduling, timely implementation, capable direction, skillful application, and continuous evaluation.

The gains from OJT in Air Force operations are numerous. With a better trained staff, the supervisor has more time to look and plan ahead and to focus on the improvement of present work methods and conditions. He has more relief from details and less worry and nervous strain; he can develop himself as a leader. The worker also benefits from OJT, because he has more opportunities for special training. This training will also help him become more useful to his unit, because he develops a sense of responsibility and a better understanding of his job and learns the value of systematic work habits. OJT may be conducted for either of two reasons: (1) upgrade training (UGT) or (2) qualification training (QT).

UGT through OJT. OJT is a planned training program. It is designed to qualify airmen, through self-study and supervised instruction. It also qualifies them to perform in an Air Force specialty (AFS) while actually working in a duty assignment of the AFS. The new OJT program consists of two parts: (1) job knowledge and (2) job proficiency development. This is known as the *dual-channel OJT concept.* Satisfactory completion of each part is necessary for eligibility and selection for upgrading.

The fundamental knowledge required for upgrade training (UGT) is contained in the Career Development Courses (CDCs). CDCs are published and administered by the Air University's Extension Course Institute (ECI). ECI is responsible for the airman's initial enrollment. They also score the end-of-volume examinations, maintain student records, and issue certificates to all enrollees who satisfactorily complete the course.

The Specialty Knowledge Test (SKT) has been removed from the skill upgrading system for the 5 level. The SKT results are now used as one of the factors in computing an airman's score in the new Weighted Airman Promotion System (WAPS). The 3 skill-level Apprentice Knowledge Test (AKT) will continue to be used for both upgrading and identifying bypassed specialists. However, when a separate 3-level CDC is available (as in the machinist specialty), the CDC Course Examination (CE) will take the place of the AKT. In AFSs where CDCs are available, the CDC usually contains all the information required to answer the questions on SKT and AKT tests. However, if references other than the CDC are required to insure complete and current coverage, then they will be listed in an "Attachment 2" to the STS and AFP 39-8. The machinist STS does not presently have an "Attachment 2" since the CDCs are the major source for SKT and AKT development.

CDCs contain information on career field basic principles and the common job knowledge requirements in each specialty. The subject matter is based on the knowledge elements listed in the approved USAF Specialty Training Standard for the specialty. The extent of training is determined by the code level shown in the STS. STSs are discussed in more detail in a later section. Each CDC is self-contained, and outside reading is not necessary to complete it.

The job proficiency development portion is accomplished through the use of Job Proficiency Guides (JPGs). The primary purpose of the JPG is to provide the airman with a reference for each task he must perform. Job Proficiency Guides have these four essential elements: (1) a list of tasks for the AFS, (2) required proficiency levels for all tasks, (3) study references of Air Force and other publications for each task assigned, and (4) space for the supervisor's certification when the prescribed proficiency level has been attained.

QT through OJT. Qualification training is different from upgrade training in that, in taking such training, the trainee is not preparing for a higher skill level. Instead, in QT, the trainee is trained on a specific task that he/she may not have performed before. For example, Airman Smart is a fully qualified 5-level specialist, but when he arrives at a new base, he finds that he will be required to bench check and repair power takeoff couplings from assigned aircraft. The problem is that he has never even seen such a coupling before and naturally does not know the procedures involved. Fortunately, his supervisor realizes this; so he enters Airman Smart in qualification training to teach him how to properly accomplish the task. There is no specified time limit for QT, nor is there a CDC involved. The supervisor determines when Airman Smart can successfully accomplish the job on his own and then signs the appropriate OJT forms certifying that he is qualified. This removes him from QT. It is to the trainee's advantage to make official entries in his OJT records when he is placed in QT, since he can show his next supervisor the areas in which he is qualified to perform work.

Exercises (636):

1. State the requirements of an effective OJT program.

2. *Situation:* A supervisor finds that he is always behind in his work, because he must spend much of his time showing his subordinates how to do their assigned tasks. Indicate the most likely cause for this.

3. Identify two reasons for establishing an OJT program.

4. Define *dual-channel concept.*

5. Name the document controlling the content of CDCs.

6. Specify the part the CDC plays in UGT.

7. Briefly explain "qualification training" (QT).

637. State why and when OJT is needed and where it is conducted and, given a hypothetical situation, identify the OJT-type training involved.

Concerning OJT, why, when, and where is it required and conducted? This portion of this text discusses these things.

Why OJT Is Needed. Air Force jobs require various combinations and degrees of skill and knowledge. Some are highly complex and require lengthy training periods; others are less complex and require less training. Most of the training for the less complex jobs is conducted through on-the-job upgrade training programs, which include self-study and proficiency training. For the more complex jobs, primary consideration must be given to the knowledge requirements. Since knowledge is easily acquired in the classroom, it follows that most airmen who are selected for training into such jobs receive their first training in technical schools. After an airman has received the appropriate training in a formal school or on the job, however, he still has to become proficient in a duty position of the AFS. An airman may become a semiskilled machinist as a result of formal training, qualifying score on the bypass specialist test, or OJT. But he must receive training on the job to become a fully skilled worker. OJT is necessary because formal schools cannot effectively teach one of the most important ingredients needed to become a skilled machinist. That ingredient is job experience.

When OJT Is Required. These are specific instances when OJT is required of an individual. For example, each unskilled basic airman who is given a directed duty assignment (DDA), upon reaching his organiza-

Maintenance Management

YOU WILL FIND THAT the Air Force, like any other business organization, consists essentially of equipment, facilities, and people. The efficient use of this manpower and equipment is the responsibility of management personnel. Air Force Manual 66–1 and Air Force Regulation 66–5 establish the maintenance system and policies which are used by all Air Force activities engaged in the maintenance of aircraft, missiles, aerospace ground equipment (AGE), and other related support equipment. Supervisors must completely understand and apply these policies and procedures to insure maximum utilization of all available resources. All Air Force personnel, military and civilian, must be trained in the use of the maintenance management system and policies to facilitate the timely accomplishment of the Air Force mission.

4-1. Maintenance Management Under AFR 66–1.

In this chapter we will cover the two maintenance management programs that are used in the Air Force today. The most common program is outlined in AFR 66–1, and is the basis for all maintenance management programs that are used by the Air Force. We will explain the function and responsibilities of the Deputy Commander for Maintenance and his staff, and give you information about the data collection, maintenance, inspection, and material deficiency reporting systems. The newest maintenance concept is based on AFR 66–5 and is called the Production Oriented Maintenance Organization (POMO), and is covered is Section 4-1a. Since these two programs are very similar, we will cover only those major areas that pertain to you as a machinist. Among these areas are the organizational structure, area of assignment, and the types of training that you could receive, outside your regular upgrade training, under the POMO concept.

642. State the main functions and responsibilities of the Deputy Commander for Maintenance (DCM), especially concerning safety and training, and specify the relationship of the machinist to those responsibilities.

The duties and responsibilities of the DCM, especially as related to the machinist, are our subject here.

Deputy Commander for Maintenance. The Deputy Commander for Maintenance, termed the "DCM," manages all of the maintenance complex. Thus, the DCM must plan, schedule, control, and direct the use of all maintenance resources to meet mission requirements. With the aid of the staff agencies, he must provide the essential guidance and direction for subordinate activities to implement and comply with assigned maintenance policies and technical instructions.

In addition, the DCM is responsibile for insuring that the maintenance performed on the assigned equipment is of high quality and that it is performed in a timely manner. This responsibility makes the success of the DCM's job dependent upon the actions of each and every specialist within the maintenance complex. Quality maintenance depends upon the integrity and concern of each individual specialist or technician, who must accomplish his assigned task regardless of the environmental conditions. You can see, then, that if you do poor quality work, it can adversely affect competence of the whole maintenance complex, including the DCM.

The DCM must also insure that effective safety programs are established and adhered to throughout the maintenance complex. He is responsible for establishing an efficient training program and for reviewing monthly training plans and schedules. He must also manage the financial operation of the maintenance organization and establish effective resource conservation programs within the maintenance complex.

Of course, the foregoing are not nearly all of the responsibilities assigned to the DCM by AFR 66–1, Volume 2. Still, even these few should be enough to point out to you the complexity of his position. As we have already stated, to effectively discharge his duties and responsibilities, the DCM must have the *complete support* of each individual assigned to him.

Exercises (642):

1. Specify the main function of the DCM.

2. Tell how the kind of work you do as a machinist effects the success or failure of the DCM.

3. Give the DCM's responsibilities concerning safety and training.

643. Concerning the basic functions of units making up the DCM's staff, give the main ones related to maintenance, the maintenance control unit's divisions, and the function and responsibilities of this and other units related to maintenance.

As a machinist-supervisor, you must understand the DCM's staff functions   our topic at this time.

DCM Staff Functions. From our discussion of the responsibilities of the DCM, you have probably already concluded that even the few we have mentioned take up much more research and work than any one person can do. For this reason, the DCM is provided with a group of staff units under his direct supervision. Of these, two, maintenance control and quality control, are responsible for the management of the quantity and quality of maintenance production. Other units, which are assigned tasks not directly associated with direct production efforts, are grouped together as management support functions and programs and mobility.

Maintenance control. Maintenance control is the staff agency that is responsible for directing the maintenance production activities, authorizing the expenditure of resources and controlling the actions required to support the mission. Maintenance control manages the planning, scheduling, directing, and controlling of all maintenance performed on assigned and transient vehicles and related equipment. To accomplish this task, maintenance control is divided into these three sections: (1) job control, (2) plans and scheduling and documentation, and (3) materiel control, which are covered in that order next.

a. The job control section. This is the section charged with the task of directing and controlling the use of maintenance resources. It must also implement the maintenance plans and schedule the accomplishment of unscheduled maintenance requirements. Job control is the section authorizing and assigning the flightline dispatch jobs and priorities to which you must respond. Also, the job control people monitor the specialist availability throughout the maintenance complex and direct their utilization in accomplishing the required maintenance tasks as they occur. This is why it is so important for each shop to notify job control when there is a change in the specialist availability in the shop or when a specialist completes an assigned task. To do their job properly, job control must know how many specialists are available for dispatch at all times.

Job control also establishes measures to manage the powered AGE equipment. They coordinate closely with the AGE dispatch unit and the shops who require the use of AGE equipment. Thus, they must know what units are available and their location. In addition, they assign job control numbers which we will discuss in more detail later in this chapter.

b. The plans and scheduling and documentation section. In this section are compiled the maintenance data for the DCM. This section also must brief the DCM on projected changes needed to meet mission requirements. Furthermore, it is the people who work in this section who compile and publish monthly and weekly maintenance plans, and they must establish schedules for compliance with TCTOs before their specified time limits.

c. The materiel control section. This section provides coordination between maintenance, on the one hand, and supply, on the other, for needed parts and equipment as such is required. It is composed of (1) the supply liaison function and (2) the production control function. Of these, the production control function is responsible for scheduling in-shop production jobs.

Quality control. This unit is responsible for insuring quality and safe maintenance. Its personnel inspect and evaluate maintenance and facilities and coordinate closely with supervisors in an effort to improve the maintenance methods. They also maintain the master technical order file for the maintenance complex. In addition, quality control administers the Maintenance Standardization and Evaluation Program (MSEP) and manages the materiel deficiency and technical order improvement reporting programs.

Management support functions. These functions, as we have stated already, perform duties not specifically related to the direct control of maintenance production. These functions are: (1) administration, (2) production analysis, (3) training management, and (4) programs and mobility, discussed next in that order.

a. The administration function. This function accomplishes all of the administrative activities for the DCM. Its personnel supervise the keypunch activity when it is assigned to the maintenance complex, and they sort out and group all AFTO Forms 349 before submitting them to the keypunch activity. They are also responsible for insuring the proper distribution of all maintenance correspondence, reports, and publications.

b. The production analysis function. It is this function which is the primary management information source for the DCM. Its personnel scan the various maintenance data reports and listings in an effort to identify weaknesses found in workcenters, in equipment end items, in maintenance practices, or in management actions. Part of production analysis's many responsibilities is to assist supervisors in proper application and interpretation of man-hour and maintenance data publications and reports. This unit also assigns work center codes.

In addition to the foregoing, this section is the control point within maintenance for the base level inquiry system (BLIS). Consequently, when a supervisor needs to know how his specialists have been used during a certain period of time—including the type of job, the time required to complete each job, and the number of times that a particular job has been done—he can request production analysis to extract that information for him from BLIS, in which all maintenance data is stored on computer tapes. Because the type of information analysis that can be obtained in this way through BLIS is extensive, it should be used by all maintenance managers to enhance their operation.

c. The training management function. This is the function which assists unit training sections in the management of maintenance training and management training requirements. Its personnel are those who schedule and monitor the maintenance management training program and consolidate unit requests for maintenance training in order to identify the total requirements for the maintenance complex. In some instances, training management may be the centralized agency for controlling and managing the UGT program. In these cases, this section performs all of the responsibilities of each unit training section.

This latter function (training management) also manages and administers the MMICS training subsystem. Under this system, all training data, including training schedules, requests, completions, due dates and historical data is stored in computers and published in various reports and listings to insure that required training is obtained in a timely and efficient manner.

Programs and mobility. This is the last function taken up in our discussion of the DCM staff. It manages the manpower, facilities, and financial resources for the DCM. It is directly concerned with the number of personnel assigned to the maintenance complex and with the positions to which they are assigned. Its personnel initiate requests for changes to the unit manpower authorizations. They also prepare the budget requirements for the maintenance complex and determine the facilities requirements for the organization.

In conclusion, the scope of the functions of the DCM staff is truly extensive. Yet, all of these functions are available to each supervisor and/or manager within maintenance and properly used, can help him/her establish the most efficient and productive maintenance operations.

Exercises (643):

1. Name the two main staff units under the DCM that are concerned with maintenance production

2. List the divisions of the maintenance control unit.

3. Match each function given in column B with its corresponding maintenance control division, found in column A, by writing the correct number-coded function (column B) beside its associated letter-coded division (column A). NOTE: Each item in column B may be matched once or more than once.

Column A

____ a. Job control.
____ b. Plans, scheduling, and documentation.
____ c. Materiel control.

Column B

1. Publishes weekly and monthly maintenance lans.
2. Schedules the accomplishment of unscheduled maintenance.
3. Has production control as one of its functions.
4. Schedules in-shop production jobs.
5. Controls flightline dispatch specialists.

4. Name the staff unit that manages the technical order improvement program.

5. List the functional units contained in the management support group.

6. Clarify briefly the responsibilities of the production analysis function, indicating how its personnel can help the maintenance supervisor.

7. Cite the DCM staff function responsible for making requests to change the unit manning authorizations.

4-1a. AFR 66-5, Production Oriented Maintenance Organization (POMO).

The policies and procedures that we have just covered for AFR 66-1 are basically the same as those found in AFR 66-5. This section will familiarize you with some of the major differences that might affect you as a machinist. We will look at how and why the organizational arrangement of POMO is determined. Then we will turn our attention to items affecting your place of assignment and the type of training that you could receive under a POMO type of maintenance concept.

643a (652—for computer answer key and feedback reference only). Identify facts concerning the organizational structure and your area of assignment under the POMO concept of maintenance.

POMO is a concept that reorganizes maintenance activities by squadrons to support either sortie production or heavy maintenance and component repairs. It is a type of maintenance operation that develops in a combat situation. How this is accomplished can be easily understood by looking at the basic concept of maintenance production and the organizational arrangement related to *POMO*.

Maintenance Production: A maintenance program, whether developed under AFR 66–1 or AFR 66–5, is concerned with doing the maintenance required and providing the basic data inputs for maintenance decisions. Activities related to these two concerns are called maintenance production. Maintenance production is servicing, repairing, testing, overhauling, modifying, calibrating, converting, and inspecting aircraft. Under the POMO concept, the maintenance complex is divided into "on-equipment" and "off-equipment" production groups.

On-Equipment Maintenance: On-equipment aircraft maintenance normally consists of aircraft launch and recovery, flight line inspections, servicing, lubricating, weapons loading, and adjusting and replacing of parts, assemblies, and subassemblies.

Off-Equipment Maintenance: Off-equipment aircraft maintenance normally consists of in-shop calibrating, repairing or replacing damaged or unserviceable parts, components or assemblies, modifying materials, and emergency manufacture of unavailable parts. The words "in-shop" are the ones that separate these work activities from the on-equipment ones. Under the POMO concept, personnel are arranged into "off and on" aircraft production groups. This will be easily seen as we look at the organizational structure under an ideal POMO situation.

Organizational Arrangement—POMO. The organizational arrangement of a POMO consists of three main squadrons. These squadrons are the Aircraft Generation Squadron (AGS), the Component Repair Squadron (CRS), and the Equipment Maintenance Squadron (EMS). Figure 4-2 shows the arrangement of the various parts of a POMO. What each of these squadrons is required to do is directly related to the type of maintenance that it is responsible for. This will also show you where you can possibly be assigned.

Aircraft Generation Squadron (AGS). The AGS is primarily concerned with on-equipment maintenance and is arranged into branches which are basically self-sufficient. Figure 4-3 shows the organizational arrangement. In the AGS of tactical fighter or reconnaissance wings, the flight line activities are formed into Aircraft Maintenance Branches (AMBs). The number of AMBs in the flight line activity is the same as the number of fighter squadrons assigned to the wing. If there are three fighter squadrons, then there will also be three AMBs. The AMBs will also have the same number as the fighter squadron that it supports. For example, if a wing has a 7th Tactical Fighter Squadron, then the AMB that supports it will be the 7th AMB. The objective is to foster rapport between aircrew and maintenance people, and to encourage more maintenance identification with the flying mission.

Component Repair Squadron (CRS). The CRS primarily does off-equipment repair of aircraft and support equipment components. This squadron takes care of the maintenance beyond the capability of the AGS and EMS. Additional tasks are fabrication of parts, maintenance and operation of aircrew training devices, and repair and calibration of precision measurement equipment (PME). The squadron is functionally divided into these branches: Accessory Maintenance, Propulsion, Conventional Avionics, Integrated Avionics, Aircrew Training Devices (ATD) and Type II Precision Measurement Equipment Laboratory (PMEL). Figure 4-4 shows the organizational arrangement of the squadron.

Equipment Maintenance Squadron (EMS). The EMS is responsible for the maintenance of AGE (support equipment), munitions, off-equipment aircraft components, and the extensive on-equipment maintenance of aircraft. This squadron also provides explosive ordnance disposal service. Figure 4-5 shows the location of the specific shops within the three branches.

Area of Assignment. Under AFR 66–1, as a machinist, you are assigned to only one area: the machine shop within the Fabrication Branch of the Field Maintenance Squadron. Under AFR 66–5, as a machinist, you will most likely be assigned to only one area; the machine shop within the Accessory Maintenance Branch of the Component Repair Squadron (see fig 4-4). As you can see, the only things that have changed are the names of the branch and the squadron. You will be doing the same job that you did under AFM 66–1. You will be mainly concerned with the off-equipment items or components. However, there will be times when you will be called upon to support either the Equipment Maintenance Squadron or the Aircraft Generation Squadron. This type of support will normally be done by dispatch.

Exercises (643a):

1. How are maintenance activities under POMO organized?

2. What does the organizational arrangement under POMO consist of?

3. What is the purpose of organizing AMBs within an AGS?

4. How is the CRS functionally organized?

5. What squadron and branch would you, as a machinist, be assigned to?

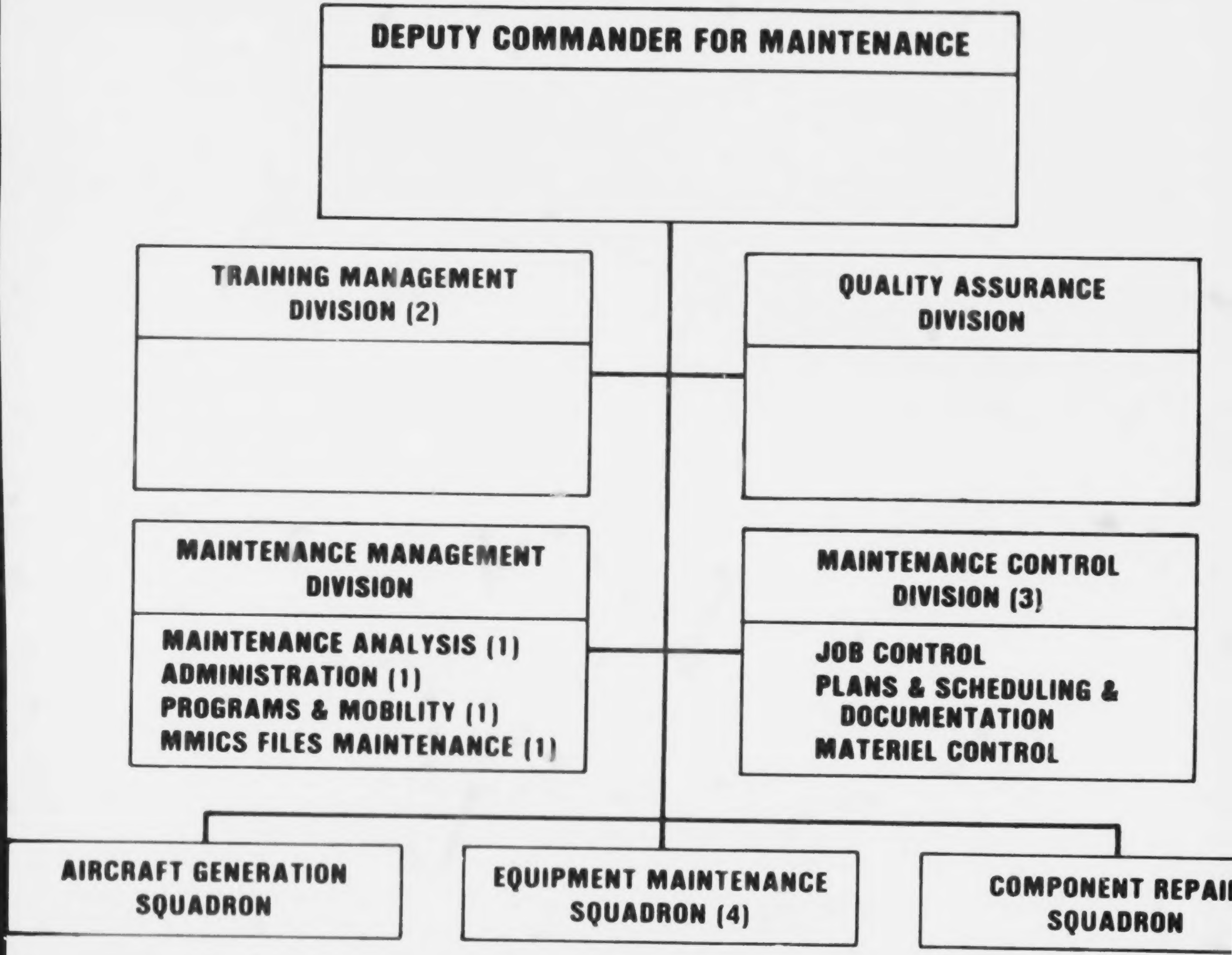

DEPUTY COMMANDER FOR MAINTENANCE
TRAINING MANAGEMENT DIVISION (2)
QUALITY ASSURANCE DIVISION
MAINTENANCE MANAGEMENT DIVISION
MAINTENANCE ANALYSIS (1)
ADMINISTRATION (1)
PROGRAMS & MOBILITY (1)
MMICS FILES MAINTENANCE (1)
MAINTENANCE CONTROL DIVISION (3)
JOB CONTROL
PLANS & SCHEDULING & DOCUMENTATION
MATERIEL CONTROL
AIRCRAFT GENERATION SQUADRON
EQUIPMENT MAINTENANCE SQUADRON (4)
COMPONENT REPAI
SQUADRON

Figure 4–2. Deputy Commander for Maintenance (POMO).

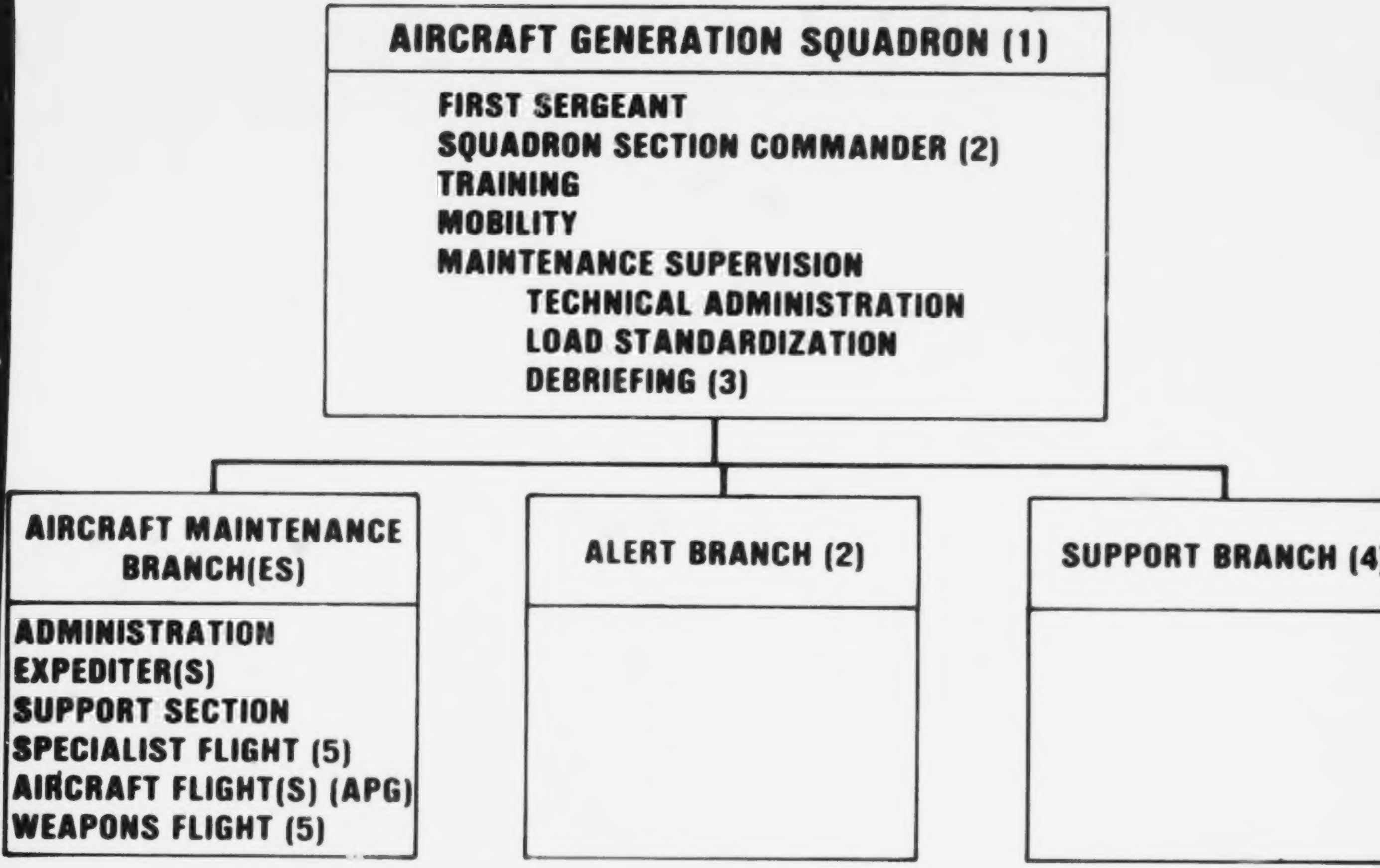

AIRCRAFT GENERATION SQUADRON (1)
FIRST SERGEANT
SQUADRON SECTION COMMANDER (2)
TRAINING
MOBILITY
MAINTENANCE SUPERVISION
TECHNICAL ADMINISTRATION
LOAD STANDARDIZATION
DEBRIEFING (3)
AIRCRAFT MAINTENANCE BRANCH(ES)
ADMINISTRATION
EXPEDITER(S)
SUPPORT SECTION
SPECIALIST FLIGHT (5)
AIRCRAFT FLIGHT(S) (APG)
WEAPONS FLIGHT (5)
ALERT BRANCH (2)
SUPPORT BRANCH (4

Figure 4-3. Aircraft Generation Squadron.

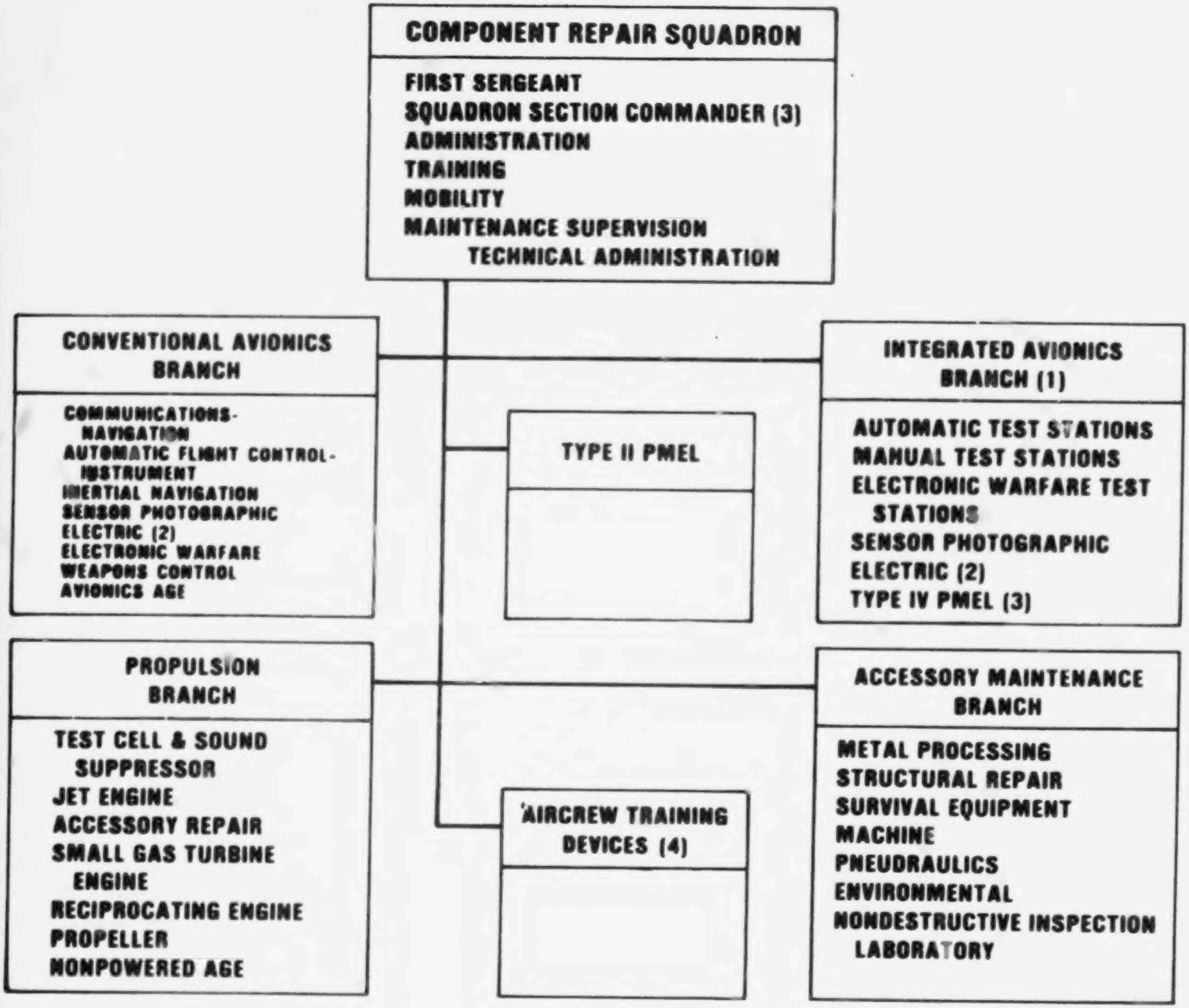

COMPONENT REPAIR SQUADRON
FIRST SERGEANT
SQUADRON SECTION COMMANDER (3)
ADMINISTRATION
TRAINING
MOBILITY
MAINTENANCE SUPERVISION
TECHNICAL ADMINISTRATION
CONVENTIONAL AVIONICS BRANCH
COMMUNICATIONS-NAVIGATION
AUTOMATIC FLIGHT CONTROL-INSTRUMENT
INERTIAL NAVIGATION
SENSOR PHOTOGRAPHIC
ELECTRIC (2)
ELECTRONIC WARFARE
WEAPONS CONTROL
AVIONICS AGE
TYPE II PMEL
INTEGRATED AVIONICS BRANCH (1)
AUTOMATIC TEST STATIONS
MANUAL TEST STATIONS
ELECTRONIC WARFARE TEST STATIONS
SENSOR PHOTOGRAPHIC
ELECTRIC (2)
TYPE IV PMEL (3)
PROPULSION BRANCH
TEST CELL & SOUND SUPPRESSOR
JET ENGINE
ACCESSORY REPAIR
SMALL GAS TURBINE ENGINE
RECIPROCATING ENGINE
PROPELLER
NONPOWERED AGE
AIRCREW TRAINING DEVICES (4)
ACCESSORY MAINTENANCE BRANCH
METAL PROCESSING
STRUCTURAL REPAIR
SURVIVAL EQUIPMENT
MACHINE
PNEUDRAULICS
ENVIRONMENTAL
NONDESTRUCTIVE INSPECTION LABORATORY

Figure 4-4. Component Repair Squadron.

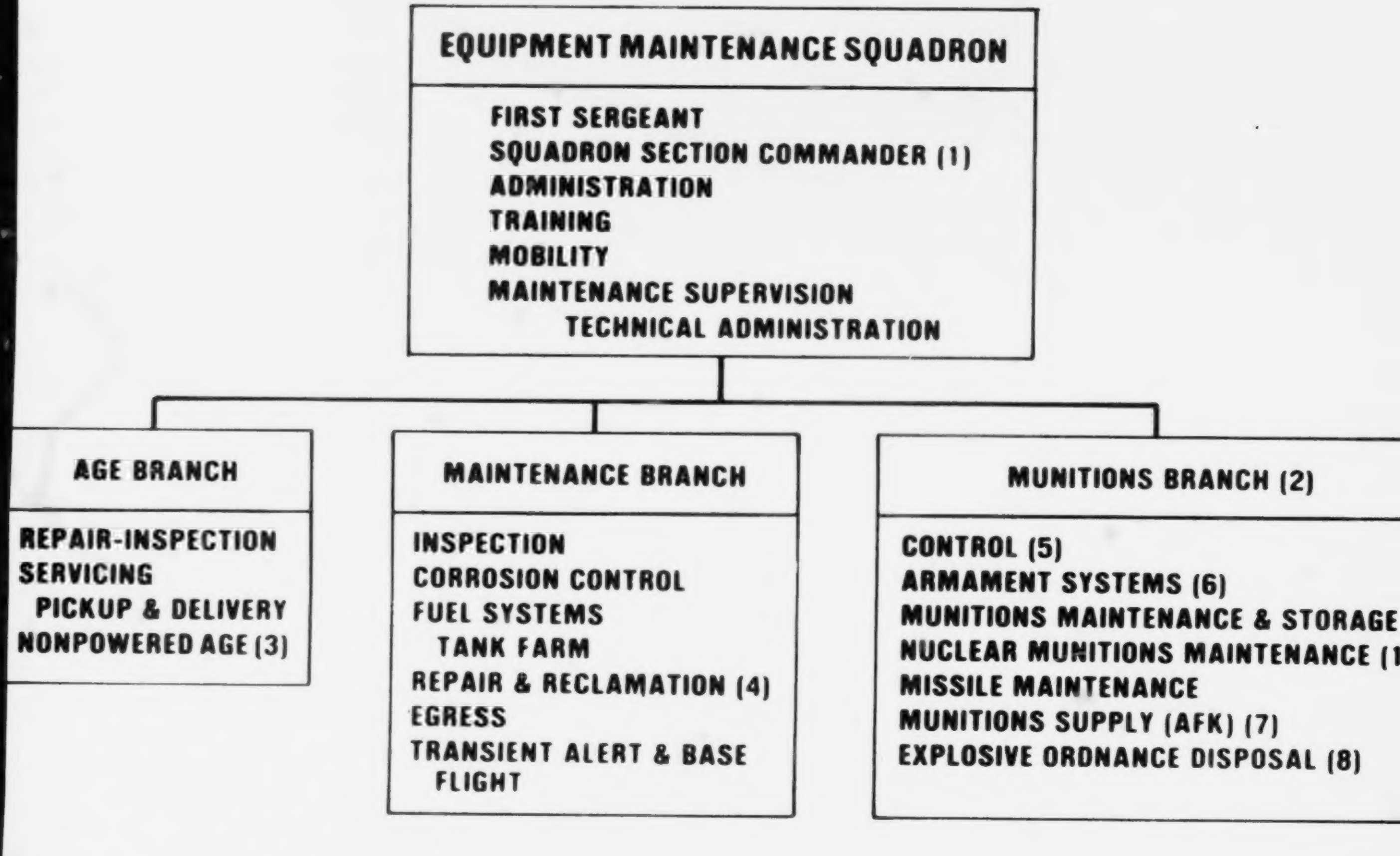

EQUIPMENT MAINTENANCE SQUADRON
FIRST SERGEANT
SQUADRON SECTION COMMANDER (1)
ADMINISTRATION
TRAINING
MOBILITY
MAINTENANCE SUPERVISION
TECHNICAL ADMINISTRATION
AGE BRANCH
REPAIR-INSPECTION
SERVICING
PICKUP & DELIVERY
NONPOWERED AGE (3)
MAINTENANCE BRANCH
INSPECTION
CORROSION CONTROL
FUEL SYSTEMS
TANK FARM
REPAIR & RECLAMATION (4)
EGRESS
TRANSIENT ALERT & BASE FLIGHT
MUNITIONS BRANCH (2)
CONTROL (5)
ARMAMENT SYSTEMS (6)
MUNITIONS MAINTENANCE & STORAGE
NUCLEAR MUNITIONS MAINTENANCE (1
MISSILE MAINTENANCE
MUNITIONS SUPPLY (AFK) (7)
EXPLOSIVE ORDNANCE DISPOSAL (8)

Figure 4–5. Equipment Maintenance Squadron.

643b. (653—for computer answer key and feedback reference only). Identify facts pertaining to training requirements of the POMO maintenance concept.

As a machinist under AFR 66–1, the only formal training you will receive will be that training associated with normal upgrade (skill level) training within your career field. This is not always the case under AFR 66–5. In addition to normal upgrade training, you could also receive cross-utilization training (CUT).

Cross-Utilization Training (CT). CUT training is that training necessary to provide you with the ability to perform a selected number of tasks that are not a part of your primary AFSC. There are two categories of CUT training: AFSC to AFSC and multiple AFSC.

AFSC to AFSC. This category enables a person to do certain tasks in only one other closely related AFSC. Training in this category is well suited for the CRS and EMS shops. For example, you, as a machinist, could be trained to do certain tasks in AFSC (427X5) airframe repair specialist. The level of training will be high enough to ensure that you can do the task(s) with little or no help. Training will consist of practial training and may include training conducted by an FTD unit.

Multiple AFSC. This category enables a person to do certain tasks that have been selected from two or more closely related AFSCs. The key words "two or more" mean that you could be trained to do certain tasks in AFSC 42755 airframe repair specialist and AFSC 42754 metals processing specialist. The potential combinations for this training are unlimited. As with AFSC to AFSC, the level of training will be high enough to insure that you can do the tasks with little or no help. Again, this training will consist of practical training and may include training conducted by an FTD unit. Regardless of the category of CUT training you receive, make sure it is documented on AF Form 797 and included in your training record. This prevents duplication of training and permits proper utilization of people. (NOTE: Cross-utilization training must not interfere with the upgrade training of 3-level personnel or the qualification training of personnel who are not qualified on the assigned weapon system).

Exercises (643b):

1. Under POMO, what formal training might you receive in addition to normal upgrade training?

2. What level of training would you be trained to under CUT?

3. Where is cross-utilization training documented?

4. What will cross-utilization training consist of?

4-2. Maintenance Systems

In this section we will examine the types of maintenance performed by Air Force machinists and the maintenance data collection system. We will discuss the use of certain maintenance data collection forms and we will also look at the procedures for controlling materials as they flow through the shops.

644. State the types of maintenance performed by the machinist and the organizational maintenance system's (OMS) responsibility for insuring maintenance is accomplished and, given a hypothetical situation involving maintenance, the level of maintenance being performed.

What are the types of maintenance which a machinist performs? These are discussed next.

Maintenance Systems. What is termed "maintenance" refers to the normal upkeep and preservation of aircraft and associated operating equipment which must be kept in reliable condition. To achieve such maintenance, it is necessary to use a system that will insure the timely accomplishment of important tasks. A system that meets this requirement is one of *regularly scheduled maintenance and repair actions.* Various levels of maintenance are charged with the responsibility of performing specific maintenance tasks. The organizational maintenance system (OMS) facility performs minor maintenance on the assigned aircraft. This is referred to as *organizational level maintenance* and can include such things as removal and replacement of parts, servicing, and various types of inspections. Field maintenance activities perform intermediate level maintenance functions. This is considered major maintenance and is *middle level maintenance.* Maintenance beyond the capability of the intermediate maintenance facilities on a base is accomplished at a depot. Thus, *depot level maintenance* is the highest level of maintenance and is performed at bases that are specifically designated to perform this function. At a depot base, they have the capability of rebuilding parts, overhauling equipment, and in some case, completely overhauling an aircraft.

You will be working primarily in the intermediate maintenance level. At this level, maintenance may be classified as (1) scheduled or (2) unscheduled. *Scheduled maintenance* is a job that can be planned in advance. Examples include TCTOs and periodic inspections. In contrast, *unscheduled maintenance* is that which is not planned. Examples of this type would be malfunctions discovered by aircraft crew chiefs and other maintenance personnel, such as a cracked wing spar or a broken generator stud on an aircraft engine.

In the Air Force, the organization to which an aircraft is assigned has the responsibility for its upkeep. In most cases, this is OMS, and it is responsible for getting the required work done, even though its personnel do not perform all of it themselves. When the work is beyond their level of maintenance, they must request assistance from the specialists in the intermediate level facilities, which, as we said, includes the machinist.

Exercises (644):

1. Specify the maintenance level in which you perform as a machinist in field maintenance.

2. *Situation:* Suppose you were assigned as a machinist to a facility specifically designated to completely overhaul certain types of aircraft. Name the level of maintenance in which you would most likely be working.

3. Indicate why OMS is responsible for insuring that the maintenance you perform on the assigned aircraft gets completed.

645. Give the purpose and clarify the operation of the maintenance data collection system and the man-hour reporting system.

That you know and understand what the maintenance data collection system and the man-hour reporting system are is assumed; so these are this segment of this volume's topics.

Maintenance Data Collection System. The maintenance data collection (MDC) system provides for the reporting of maintenance actions as they are accomplished. The recorded information is then keypunched and processed in report form for management information requirements.

There are many and varied uses made of MDC information, starting at work centers and running through the complete spectrum of maintenance and materiel management. This information is also provided to industry for consideration in new equipment design. Specific uses of the output products from computer programs are included in USAF directives. These uses are also included in command regulations and manuals that prescribe management requirements.

Base level use of maintenance data is prescribed in AFM 66-267, *Maintenance Data Collection System.* At base level, the MDC system provides the means of managing assigned equipment resources and planning and scheduling maintenance. It also provides the means for validating and initiating corrective action on maintenance problems. The MDC system is a key source of information for assessing maintenance requirements. More specifically, at base level, the MDC system provides:

- Production credit information regarding the type of work accomplished, the work center(s) that did the work, and the equipment on which the work has been accomplished.
- Equipment maintenance schedules and inventory information for maintenance requirements established on a calendar basis.
- Direct labor hour expenditures by work center and type of equipment, in either detailed or summary form. This includes labor expended for tenant activities on special projects.
- Material failures and equipment discrepancies, in composite form by type and model of equipment.
- Configuration status accounting for both outstanding and accomplished modifications.

Data in the MDC system is made available to base level maintenance activities through daily or monthly

642 - 2. The DCM is responsible for the quality and timeliness of maintenance performed on assigned equipment; therefore, if your work as a machinist is substandard, it will distract from the DCM's ability to successfully accomplish his job.

642 - 3. He is responsible for insuring that an effective safety program is established and adhered to within the maintenance complex and for insuring that competent training programs are established.

643 - 1. These are: (1) maintenance control and (2) quality control.

643 - 2. (1) Job control, (2) plans and scheduling and documentation, and (3) materiel control are these divisions.

643 - 3. a. 2, 5
b. 1
c. 3, 4

643 - 4. Quality control manages this program.

643 - 5. (1) Administration, (2) production analysis, (3) training management, and (4) programs and mobility belong to this group.

643 - 6. It analyzes maintenance data reports to identify trends or weaknesses in workcenters, equipment maintenance practices or management actions. Its people can furnish the supervisor with information concerning his man-hour utilization, trends in type of work performed, and time spent on various types of work.

643 - 7. Programs and mobility has this responsibility.

643a - 1. The maintenance activities are organized by squadrons to support either sortie production or heavy maintenance and component repairs.

643a - 2. The organizational arrangement consists of the Aircraft Generation Squadron, the Component Repair Squadron, and the Equipment Maintenance Squadron.

643a - 3. The objective is to foster rapport between aircrew and maintenance people and to encourage more maintenance identification with the flying mission.

643a - 4. The CRS is functionally divided into these branches: Accessory Maintenance, Propulsion, Conventional Avionics, Integrated Avionics, ATD, and Type II PMEL.

643a - 5. You would be assigned to the CRS, Accessory Maintenance Branch.

643b - 1. CUT.

643b - 2. The level of training will be high enough to insure that you can do the task(s) with little or no help.

643b - 3. CUT is documented on AF Form 797 and included in your training record.

643b - 4. CUT consists of practical training and training conducted by an FTD unit.

644 - 1. The intermediate level is your level.

644 - 2. You would work at the depot level.

644 - 3. The reason is that aircraft are assigned to OMS, and in the Air Force, the owning organization is assessed with the responsibility for the upkeep.

645 - 1. Its purpose is to provide for recording, processing into report form, and disseminating information on maintenance actions for use by supervisors and managers at all levels.

645 - 2. This is done through daily and monthly reports.

645 - 3. It is used to:
a. Identify equipment configuration.
b. Assure accomplishment of TCTOs.
c. Project workload and scheduling requirements.
d. Provide mechanized historical records for designated equipment.
e. Provide accurate configuration status for high cost or mission significant items.

645 - 4. He uses the (1) Maintenance Personnel Listing and the (2) Monthly Man-hour Summary for this purpose.

645 - 5. It is obtained from MDC forms turned in by each work center during the month.

645 - 6. The number of people authorized for his work center is largely based on how much nonproductive or undocumented time is expended, and the accomplishment of the shop mission will suffer if the percentage of nonproductive labor is allowed to remain too high.

645 - 7. This is done with special codes, which are listed inn TO 00–20–2 and aircraft and equipment code manuals (–s06 technical orders).

646 - 1. These are: (1) the AFTO Form 349, Maintenance Data Collection Record, and (2) the AFTO Form 350, Reparable Item Processing Tag.

646 - 2. It is used for both (1) documenting personnel actions on equipment end items and (2) recording productive-indirect labor time.

646 - 3. TO 00–20–2 and the related 00–20–2 series TOs do this.

646 - 4. the 195 means the 195th day of the year, and the 0002 means the 2nd job of the day or reporting period.

646 - 5. This is the equipment classification code.

646 - 6. This code identifies a specific type of aircraft, equipment, or specific type of work in support of that equipment.

646 - 7. TO 00–20–2 has this list.

646 - 8. The second character of the identification number is the first character or prefix of the equipment classification code.

646 - 9. It is a one digit number that identifies the position of an engine on an aircraft when work is performed on an engine or component parts.

646 - 10. The labor category code is used here for this purpose.

646 - 11. AFM 300–4 and the applicable equipment –06 code manuals do this.

646 - 12. The top part of the AFTO Form 350 is a routing tag that is attached to equipment components as they go throgh the maintenance shops for repair. It is also the source document for filling out the AFTO Form 349 for work done on that equipment. The bottom part of the tag is used by the production control activity to keep a running record of the equipment status as it is being repaired.

647 - 1. The Reparable Processing Center (RPC) or Reparable Assets Control Center (RACC) does this.

647 - 2. It means "due in from maintenance" and is used to identify high value or limited availability items which must be returned to Supply after processing through the maintenance shops.

647 - 3. This is AWM, which means awaiting maintenance.

647 - 4. It means *awaiting parts*, and it is used when repairs on an item must be halted until an ordered part is issued by Supply.

647 - 5. Return the gear box to Supply as a NRTS item, using the applicable NRTS code.

648 - 1. The purpose is to locate and repair equipment defects and their causes before they produce major damage or component failure.

648 - 2. These are: (1) the preinspection phase, (2) the look phase, (3) the fix phase, and (4) the postinspection phase.

648 - 3. It is the postinspection or followup phase.

648 - 4. It has developed the –6 technical orders, which list all of the items to be checked.

649 - 1. The authorized concepts are the (1) periodic, (2) phased, and (3) isochronal.

649 - 2. The *basic postflight* is conducted after each flight to determine whether or not the aircraft is suitable for another flight. In contrast, the *hourly postflight* is not conducted after each flight but rather after the flight in which a specified number of flying hours was accumulated. It is also a more in-depth inspection than is the basic postflight.

649 - 3. These are the: (1) preflight, (2) thru-flight, (3) basic postflight, (4) hourly postflight, and (5) periodic inspections.

649 - 4. This is the isochronal concept.

650 - 1. It is to establish data feedback methods to responsible activities so that action can be initiated to correct and prevent materiel, design, and quality deficiencies.

650 - 2. a. 1
b. 2
c. 2
d. 2

e. 1
f. 1
g. 2
h. 1
i. 1
j. 2

650 - 3. They are transmitted electronically using DD Form 173.

650 - 4. They are transmitted by AUTODIN using Standard Form 368.

651 - 1. The reason for the supervisor being interested here is to premit him to identify work bottlenecks and training requirements within his shop.

651 - 2. He likely reviewed the aircraft history file.

651 - 3. Two graphs.

AU GAFS, AL. (833315)900

53150 01 7702

CDC 53150

MACHINIST

(AFSC 53150)

Volume 1

Machine Shop Fundamentals

Proficimus More Irretenti

Extension Course Institute

Air University

Prepared by
MSgt Teddy L. Ford
3340 Technical Training Group
USAF School of Applied Aerospace Sciences (ATC)
Chanute AFB, Illinois 61868

Reviewed by
Janice M. Beck, Education Specialist
Extension Course Institute (AU)
Gunter AFS, Alabama 36118

PREPARED BY
3340 TECHNICAL TRAINING GROUP
USAF SCHOOL OF APPLIED AEROSPACE SCIENCES (ATC)
CHANUTE AIR FORCE BASE, ILLINOIS

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS CAREER Development Course will help you qualify in the upgrade knowledge requirements for the machinist specialty. As the self-study portion of your on-the-job training program, it deals with job-related knowledge requirements for machinists. CDC 53150, consisting of four volumes, contains the upgrade knowledge that you need in order to progress from 3 to the 5 skill level of your career field ladder. Basically, Volume 1 contains information about your career field, security, safety, shop drawing, hand and special tools, and hardware removal and replacement. Volume 2 provides information on the properties and characteristics of various metals, as well as information on lathe, drill press, and contour machine work. Volume 3 covers milling machines, shapers, grinding machines, and the inspection of machine parts. Volume 4 discusses tool design and fabrication, technical publications, and supervision and management systems.

In addition to satisfactorily completing this course and the course examination, you must satisfy on-the-job proficiency requirements of your unit OJT program before you advance in skill level. Therefore, you should not expect this course to be an "Aladdin's genie" that will grant you every wish. Instead, you should expect it merely to contain the knowledge required for advancement in your career field. You must study to acquire this knowledge. However, you may have already acquired much of this information from your experience as an Apprentice Machinist.

Now note the chapter titles on the contents page for Volume 1. Chapter 1 covers career ladder progression and the duties and responsibilities of the various skill levels within the machinist specialty; Chapter 2, the security classification system, communication security, the Air Force Supply System, and property accountability; Chapter 3, shop and flight line safety, plus ground accident reporting; Chapter 4, shop drawings; Chapter 5, hand tools, special tools, and layout work; and Chapter 6, removal and replacement techniques for studs, plugs, screws, and inserts.

Each chapter has numbered sections that are broken down into objectives on individual knowledges. Read each objective; then complete it by reading the text and doing the review exercises at the end of each textual segment. Check your answers with those given at the end of the volume. The exercises should help you to determine whether you have attained each objective and will reinforce your learning of the information that you need. When you complete the volume, use the volume review exercise in a similar manner. Both types of exercises can help you greatly if you use them as testing devices to tell you what your areas of weakness are and as teaching devices to emphasize for you the important points that you should remember.

Code numbers appearing on figures are for preparing agency identification only.

Note that in this course, we shall be using the singular pronouns *he*, *his*, and *him* in their generic sense, not their masculine sense. The word to which they refer is *person*.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOXC, Chanute AFB IL 61868. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on the course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercises, and Course Examination), consult your education officer, training officer, or NCO as appropriate. If they can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate and current as of June 1976.

Contents

Page

Preface .... *iii*

Chapter

1 Machinist Career Field 1

2 Security and Property Accountability 7

3 Shop and Flight Line Safety 20

4 Shop Drawings 28

5 Hand and Special Tools 46

6 Studs, Plugs, Screws, and Inserts 76

Bibliography 98

Answers for Exercises 99

CHAPTER 1

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your acheivement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Machinist Career Field

HAVE YOU EVER stopped to think of how your job as a machinist is related to the rest of the metalworking career field? Considering the fast pace involved with attaining your present position, you probably haven't. As you study this chapter, you will learn how the machinist specialty is organized in relation to the metalworking career field. Also, you will become better acquainted with the numerous duties that you will be confronted with as you progress up the machinist career field ladder.

Every craftsman needs some background information about his specialty. The purpose of this chapter is to provide a portion of that background knowledge. It deals with the career ladder progression and the duties and responsibilities of the various skill levels within the machinist field.

1-1. Machinist Career Ladder

A very important factor in advancement in the Air Force is an understanding of the career field progression process. In this section, we shall discuss what your Air Force specialty code means and the advancement process by skill levels to the position of metalworking superintendent.

001. Interpret Air Force Specialty Code 531XO.

A career field is made up of a group of positions, Air Force Specialties (AFSs), requiring common qualifications. An AFS is identified by title and code. The code is made up of five digits called Air Force specialty code (AFSC). The AFSC identifies the major career field, the proficiency level, and the career field subdivision.

Now, let's examine your present AFSC, which is 53130. In an AFSC, the first three digits identify the major career field; the fourth digit identifies the proficiency or skill level; and the fifth digit, in conjunction with the other digits, identifies the subdivision or specialty. Therefore, "531" identifies your major career field, which is the metalworking career field. All AFSCs within that career field begin with "531" (metals processing—53131, air frame repair—53133, etc.).

The next (4th) digit identifies the skill level. Since this is a "3," you would be classified as semiskilled (3 skill level). As you progress up the career ladder in the machinist field, the fourth digit changes to reflect your increased proficiency (53150—skilled, 53170—advanced skilled). An "X" may also be used in the fourth position (531X0); however, it does not reflect a particular proficiency level but is used when referring to *all* skill levels within an AFS.

The "0," in conjunction with the other digits in AFSC 53150, identifies the machinist subdivision within the metalworking career field. It distinguishes the machinist specialty from other specialties in the metalworking career field: for example, 5313*3* identifies the corrosion control specialty, 5313*5* identifies the nondestructive inspection specialty, etc. A graphic display of the AFSC that you are training for (53150) is as follows:

531 . . . Major Career Field . . . Metalworking
5 . . . Skill Level . . . Skilled
0 . . . Career Field Subdivision . . . Machinisit Specialty

Exercises (001):

1. In AFSC 53150, what does the "531" indicate?

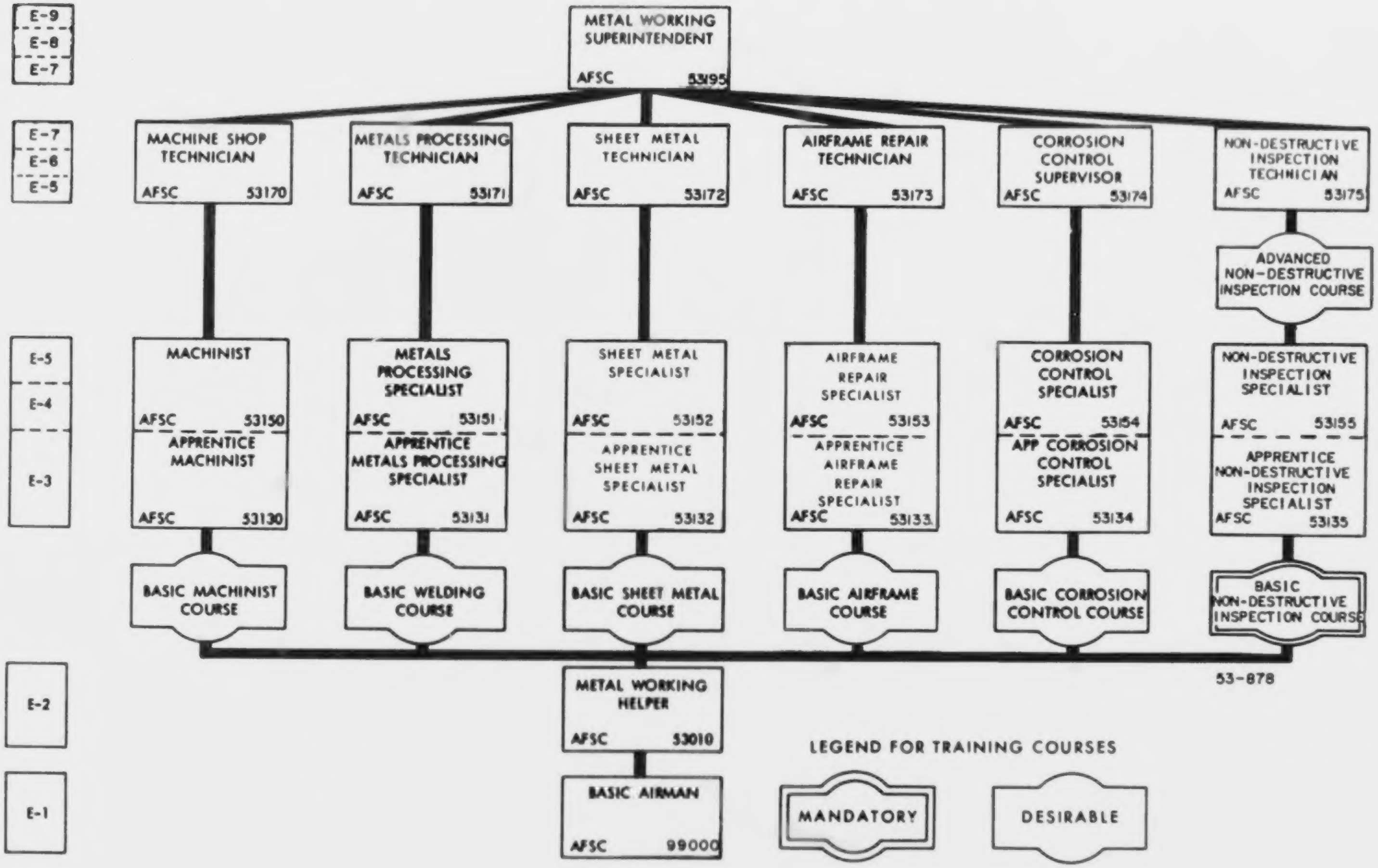

E-9
E-8
E-7
METAL WORKING SUPERINTENDENT
AFSC 53195
E-7
E-6
E-5
MACHINE SHOP TECHNICIAN
AFSC 53170
METALS PROCESSING TECHNICIAN
AFSC 53171
SHEET METAL TECHNICIAN
AFSC 53172
AIRFRAME REPAIR TECHNICIAN
AFSC 53173
CORROSION CONTROL SUPERVISOR
AFSC 53174
NON-DESTRUCTIVE INSPECTION TECHNICIAN
AFSC 53175
ADVANCED NON-DESTRUCTIVE INSPECTION COURSE
E-5
E-4
E-3
MACHINIST
AFSC 53150
APPRENTICE MACHINIST
AFSC 53130
METALS PROCESSING SPECIALIST
AFSC 53151
APPRENTICE METALS PROCESSING SPECIALIST
AFSC 53131
SHEET METAL SPECIALIST
AFSC 53152
APPRENTICE SHEET METAL SPECIALIST
AFSC 53132
AIRFRAME REPAIR SPECIALIST
AFSC 53153
APPRENTICE AIRFRAME REPAIR SPECIALIST
AFSC 53133
CORROSION CONTROL SPECIALIST
AFSC 53154
APP CORROSION CONTROL SPECIALIST
AFSC 53134
NON-DESTRUCTIVE INSPECTION SPECIALIST
AFSC 53155
APPRENTICE NON-DESTRUCTIVE INSPECTION SPECIALIST
AFSC 53135
BASIC MACHINIST COURSE
BASIC WELDING COURSE
BASIC SHEET METAL COURSE
BASIC AIRFRAME COURSE
BASIC CORROSION CONTROL COURSE
BASIC NON-DESTRUCTIVE INSPECTION COURSE
53-878
E-2
METAL WORKING HELPER
AFSC 53010
E-1
BASIC AIRMAN
AFSC 99000
LEGEND FOR TRAINING COURSES
MANDATORY
DESIRABLE

Figure 1-1. Metalworking career field.

2. Why is an "X" sometimes used in the fourth-digit position of an AFSC?

3. How does the last digit function in AFSC 53130?

002. Indicate the primary qualifications and factors involved or required in progressing from a metalworking helper to a metalworking superintendent through the machinist career field ladder.

There are three basic skill levels in the machinist specialty—3,5, and 7 skill level.

A fourth skill level (53195 at the 9 skill level) is attainable by the machinist, though it is not specifically a part of the specialty. This 9 skill level (metalworking superintendent) is the top rung of all the specialties within the metalworking career field, as shown in the Metalworking Career Field Chart (fig. 1-1). Progressing to this 9-level position looks simple enough on paper, but let's examine what is really involved in the advancement process.

When airmen are assigned to the metalworking career field during basic training, they are given the AFSC 53010. This code identifies them as being *unskilled* and is common to all six specialities within the career field. Airmen who are to be trained as machinists progress from this unskilled position to the 3 skill level in one of three ways. Most are sent to the formal technical training school at Aberdeen Proving Grounds in Maryland. Others are sent directly to the field and entered into an on-the-job training (OJT) program similar to the one in which you are presently involved. A few airmen, because of previous machinist experience, are given the opportunity to take a by-pass specialist test. Upon passing the test, they are awarded a 3 skill level and sent directly to a duty assignment.

Progression from the 3 skill level or apprentice machinist to the 5 skill level (skilled machinist) is accomplished only through OJT. This, as you probably know by now, consists of both knowledge training and proficiency training. (A detailed discussion of OJT and how to conduct it will be included later in this course.) Minimum time requirements for OJT at various levels are contained in *AFM* 50-23, *On The-Job Training*.

Before the 7 skill level (machine shop technician) is awarded, an airman must first be promoted to the rank of staff sergeant (E-5). Then he again enters an OJT program for a specified time. When he has successfully completed the requirements of this OJT program, he can be upgraded.

An airman must be a master sergeant to be awarded a 9 skill level (metalworking superintendent). Also, he must pass the USAF Supervisory Examination and either work in a 9-level position for at least 6 months or be selected for promotion to senior master sergeant (E-8).

As you can see, there is a lot of work and study involved in reaching the 9 skill level. Therefore, *now* is the time to develop good study habits. They will prove invaluable to you as you progress up the career ladder.

Exercises (002):

1. List three ways that an airman might progress from AFSC 53010 (metalworking helper) to AFSC 53130 (apprentice machinist).

2. What AFSC in the metalworking career field is reached only through OJT and has no requirement for any specific rank?

3. A "rank" factor is involved in advancing to two of the skill levels in the advancement process. List the two levels and the required rank for each.

4. What can you, as a 5-level trainee, do *now* to enhance your chances of progression up the machinist career field ladder?

1-2. Duties and Responsibilities

In the previous section, we discussed the progression up the career field ladder and you learned that there are several positions that you will fill as you advance up that ladder. There is, however, more to that progression than simple advancement. Each step up the ladder will present you with new and more difficult problems, as well as increased responsibility. In accomplishing the following two objectives, you will learn some of the duties and responsibilities of the apprentice machinist, machinist, machine shop technician, and metalworking superintendent.

003. Analyze the difference in responsibilities between an apprentice machinist [3 level] and a machinist [5 level].

Apprentice Machinist. As we have stated earlier, a 3 skill level means semiskilled or apprentice. As an apprentice machinist, you are expected to know the general principles of metal machining operations such as drilling, milling, turning, shaping, grinding and sawing. In addition, you should know the basic steps involved in the removal and replacement of broken or damaged bolts, studs, and screws. Although you are not expected to be highly proficient at these operations, you *are* expected to try your best to complete each assigned task satisfactorily. As part of your training, you will most likely be assigned to assist skilled machinists in the performance of their tasks. Use such situations to your advantage by observing each operation attentively and by questioning those portions of the tasks that are not clear to you.

Even as a semiskilled machinist, you have responsibilities as well as duties. You have a responsibility to the Air Force to take an *active* interest in your training and to become productive (skilled) within the specified training time period. You also have a big responsibility to yourself to take *pride* in every job that you do, whether it is completing this CDC or cleaning and painting shop machinery. You will find that doing your best on the undesirable jobs, as well as on the more interesting ones, will make your job more satisfying and rewarding. It will also make it easier for you to attain your 5 skill level, which you must have to be eligible for promotion to A1C (E-3), and will pave the way for future promotions.

Machinist. Since you are striving to attain the 5 skill level, a good understanding of the duties and responsibilities for that position is necessary. Therefore, it would be to your advantage to read carefully the specialty description for a machinist in AFM 39-1, *Airman Classification Manual.* This description states that the machinist operates metalworking machines in fabricating, reworking, and repairing metal parts. By itself, this work is very similar to what an apprentice machinist is required to do. The difference is that the skilled machinist is expected to perform these operations proficiently with little or no supervisory aid. The specific duties and responsibilities of the skilled machinist include:

- Manufacturing and reworking machined parts.
- Assembling and fitting machined parts.
- Maintaining hand and machine tools.
- Supervising machine shop personnel.

A machinist must know how to use precision measurement tools; make and use drawings; and make work and tool setups on the drill press, lathe, grinder, shaper, milling machine, and contour machine. He must be able to use machinist charts and tables; make calculations; select cutting tools; select speeds and feeds; and perform various machine tool cutting operations, using the appropriate machine. He must know how to assemble and fit together metal parts and fasten them with machine screw, bolts, rivets, and press fits. He must also be able to remove burrs and projections, using handtools such as files, stones, chisels, and sheet abrasives. He must be able to perform various operations involving the use of an electric or hand drill, reamers, taps, and dies. He must know how to extract damaged studs, plugs, and pins; press bushings and bearings in place; assemble gears, shafts, and pins install and level machine to insure accurate dimensions in machined work; and sharpen milling cutters, drills, reamers, tool bits, taps, and hand cutting tools. Finally he must know how to determine the appropriate operation and what power or handtools are suitable for the job.

In addition to knowing how to perform the skills of the trade, the machinist has responsibilities in the areas of supervision and training, assigning work, evaluating performance, and demonstrating the use of tools and equipment.

As a 5 level, you could be called on to take charge of a special work detail involving several individuals or even to temporarily take over the operation of an entire shop. Also, you will probably have the responsibility of training other apprentice machinists to the 5 level. In other words, a skilled machinist has a responsibility to develop his sense of logic and reason, as well as the mechanical skills required to perform his varied duties.

Exercises (003):

1. List the two key responsibilities of an apprentice machinist.

2. List the four basic areas of duties and responsibilities for the 5-level machinist.

3. Briefly state the biggest difference in the responsibilities of the apprentice machinist (3 level) and machinist (5 level).

004. Given a list of duties and responsibilities, match them with the most appropriate skill level (7 skill level or 9 skill level).

Machine Shop Technician. The machine shop technician (7 skill level) designs and machines precision tools, parts, and assemblies; inspects machine work; and supervises machine activities. More specifically, his duties and responsibilies include the following:

- Advising on metal machining, design, and production problems.
- Inspecting in-progess and completed machine work for quality of workmanship and serviceability.
- Supervising metals machining techniques and maintenance of machinery and equipment.
- Supervising machine shop personnel.

The machine shop technician must know how to design and make precision tools, gages, dies, and jigs; calculate cutting speed for turning special threads; perform all types of difficult machining operations; and determine the repairability of machined parts, the need for heat treating, and the need for repair or replacement of gages, jigs, or dies. He must be able to determine whether or not machined parts conform to specifications and make precision measurements to insure the accuracy of dimensions. He must be able to instruct the personnel in his shop in work layout, in setting up lathes and other shop machines for various machining operations, and in machine adjustment and maintenance.

In his supervisory role, the machine shop technician supervises shop personnel in machine tool setup, in machine cutting operations, in hand operations, and in bench assembly fitting and adjusting of machined parts. He supervises the design and manufacture of precision tools, dies, and jigs and the proper use and maintenance of machines. He assigns work and coordinates supply procedures and equipment requirements. He follows good maintenance and personnel management procedures. He coordinates work schedules with other affected shops and activities.

As you can see, the machine shop technician's job pertains less to the performance of machinist skills and more to advising, controlling quality, training, and supervising. The farther up the career ladder that you go, the more you will find increased emphasis on supervision and less on actually performing the machinist skills. The top positions of a career field are most effectively filled by personnel who have had actual supervisory experience. The gradual increase in supervisory responsibilities from the apprentice machinist to the metalworking superintendent is designed to provide that experience. Thus, as you move up the ladder, you are continually preparing yourself for the next higher position.

Metalworking Superintendent. Let's take a look now at the highest position in the machinist ladder, the metalworking superintendent, AFSC 53195. The metalworking superintendent's job is to coordinate and supervise the work of the machine shop, metals processing shop, sheet metal and airframe repair shops, and corrosion control and nondestructive inspection activities. His duties and responsibilities are to:

- Plan and organize metalworking activities.
- Direct metalworking activities.
- Establish and conduct on-the-job training for metalworking personnel.
- Inspect and evaluate metalworking activities.
- Perform technical metalworking functions.

The metalworking superintendent plans workloads and work assignments, establishes production controls and work standards, and prepares and analyzes reports and graphs in the area of maintenance management. He establishes requirements for equipment and supplies and develops organizational charts to establish lines of authority and to assign specific responsibilities. He evaluates machine and hand metalworking operations and directs the use, maintenance, and repair of machinery tools and equipment. He expedites work to meet estimated completion dates. He recommends personnel actions, such as reclassification, grade adjustment, and discipline; rates subordinates for efficiency; and reviews efficiency ratings made by supervisors. He directs a continuous program of on-the-job training for personnel at all skill levels. He reviews training charts to determine the status of training and determines the need for future training.

The metalworking superintendent tests new equipment and operates machine in fabricating new parts of reworking reparable components. He decides whether or not it is more practical to repair or manufacture parts and whether or not it is necessary to condemn parts or make material substitutions. He establishes and revises shop procedures to conform to directives received from higher authority.

There is no assurance that you will eventually become a metalworking superintendent, even though you apply yourself with the utmost diligence to your job; but taking everything into consideration, a technician in the machinist ladder has as good a chance as the technician in any of the other ladders in the metalworking career field.

Exercises (004):

In the following, match the duties and responsibilities with the most appropriate skill level.

a. 7 skill level (machine shop technician).
b. 9 skill level (metalworking superintendent).

—1. Make in-progress checks of quality of workmanship.
—2. Develop organizational charts to establish lines of authority.
—3. Instruct in machine maintenance.
—4. Directly supervise shop personnel in designing and manufacturing precision tools, dies, and jigs.
—5. Determine validity of proposed disciplinary actions.

Security and Property Accountability

ONE OF THE biggest tasks faced by the United States Air Force is protecting and safeguarding official and government-owned property. In this chapter we shall discuss your responsibilities in two basic areas: (1) communications and operations security, and (2) property accountability. It is extremely important for each of us to do our part within the overall security and property accountability programs. This chapter will help you to understand what is expected of you and how you can help to strengthen these programs.

2-1. Security

The degree to which you will be involved with security will depend on the mission of the base at which you are assigned, the type of equipment for which the base is responsible, and the location of the base. However, regardless of the degree of involvement, every person in the Air Force—military or civilian—must be security conscious. In fact, the people who seldom work with classified information may be a greater danger to security simply because they are less aware of the importance of safeguarding security information.

005. Indicate the difference between information that is classified, unclassified and of possible intelligence value.

Classified information is official information, the safe guarding of which is necessary in the interest of national security. The target for a strategic bomber wing would be classified information.

Unclassified information is information that does not require the use of security safeguards but the disclosure of which may be subject to control for other reasons. For example, that fact that several airmen from the bomber base are suddenly sent TDY is unclassified information. Also, the fact that several of a base's normal commitment of bombers are no longer on the base is unclassified. However, by putting both of these pieces of information together, a person could determine that a certain number of particular type of aircraft were deployed together with ground support personnel. This could be vitally important to an enemy country involved in actions against the United States or one of our allies. Therefore, both of the pieces of information become of possible intelligence value.

Thus, a bit of unclassified information by itself may not be of any intelligence value; however, when we gain knowledge of another bit of related information that together give us an insight into a classified plan each bit of information then becomes *unclassified but of possible intelligence value*. Therefore, you should always keep quiet about any information, regardless of how or where you obtained it.

Exercises (005):

1. List the three kinds of official information.

2. A master target plan for strategic missiles is ________________ information.

3. The fact that the Air Force has sent Captain Jones to an area of undeclared war is ________________ information.

4. Captain Jones is a demolition expert. Is this information by itself classified?

5. If the information in questions 2 and 3 were combined, the information would then become ________________.

006. Determine the required classification of given types of official information.

The basic regulation which covers security is the *DOD Information Security Program Regulation* (DOD ISPR 5200. 1-R). You are probably more familiar with the supplemental regulation to the DOD regulation, which is AFR 205-1, *Information Security Program*. The two publications should always be filed together and you should become familiar with them.

Classified Information. Defense information is classified according to its importance. The highest classification is given the greatest amount of protection. The three categories of classified information in the order of their importance are Top Secret, Secret, and Confidential.

If the information is such that its unauthorized disclosure could result in *exceptionally grave damage* to the national security, it is classified as Top Secret.

The Secret classification applies to information of which the unauthorized disclosure could result in *serious damage* to the national security.

The Confidential classification is applied to information if its unauthorized disclosure could reasonably be expected to cause *damage* to the national security.

Unclassified Information. Unclassified official information does not require safeguarding but may be subject to control for other reasons. Some unclassified information requires control in the public interest and is thus labeled "For Official Use Only." This designation applies to certain things that must be withheld from widespread distribution to the public. An example of this type of information would be notification of a shipment of personnel records. Such information would be unclassified but is labeled "For Official Use Only."

Exercises (006):

1. Information that could lead to an armed attack against the United States or its allies if it were disclosed would be identified as ______________ information.

2. Your hospital records are what type of information?

3. If disclosure of the information would not be in the best interests of the nation, the information is identified as ______________ information.

4. Define Secret information.

007. State how the major modes of transmission should be used for given types of official information.

For information to be useful in conducting official business, it must be passed from one person or place to another. Although there are many ways or modes of transmitting information, we shall limit our discussion to the four most common types: mail, telephone, radio, and messenger. Each of these modes has certain advantages and disadvantages, and some of them are more in conformity with security requirements than others.

Mail. Within our country, mail is handled only by the United States Postal Service. Therefore, it is given some protection. Registered mail requires special handling by the postal service. When the mail carrier brings you a registered letter, you must sign a receipt. Some advantages of using the mail is that the information is given some protection, it is inexpensive, and registered mail must be "receipted for." A disadvantage is that mail service is slow. Also, mail could get into the wrong hands; therefore, *only* information classified as *Secret or below* can be sent by mail.

Telephone. The telephone is a very convenient and speedy mode of communication. It has the advantage of minimizing distance and of making person-to-person messages more direct. In other words, you can talk to a person in the next office, another state, or halfway around the world almost as though the two of you were together in the same room. While speed, convenience, and directness are prominent advantages of the telephone, the common telephone has one big disadvantage that outweighs all of the advantages. That disadvantage is the fact that telephone conversations are *extremely* easy to monitor (listen in on). In fact, a telephone receiver left lying temporarily on a desk will pick up the voices and conversations within the room. You can readily understand the serious consequences that could result if classified information were being discussed in the room and the wrong person was monitoring the call. As a telephone user, you must always assume that the *wrong person* is listening in on all phone conversations to and from military installations. Always keep in mind that the common telephone is *not* to be used for transmitting any type of classified or sensitive information.

Radio. In radio communication, an antenna is used to send radio waves (signals) through the air. When official codes and ciphers are used to encrypt classified information, radio is considered to be a secure mode of communication for all classifications of information. At each Air Force base, there are usually people who are trained to encrypt classified radio messages. Even though the radio can be considered secure with the use of codes and is a quick and convenient mode of communication, it has some disadvantages. It can be easily monitored, atmospheric interference can interrupt the transmission, and the person sending the message has no quick way of identifying the person receiving the message. Therefore, the radio is sometimes undependable.

Messenger. Information sent by messenger is handcarried from the sending office to the receiving office. The advantages of using a messenger are that (1) the material is more secure, (2) receipts are required, and (3) material sent in this way is usually not subject to inspection. However, this method is slow and expensive when compared to other modes of communications. All types of classified information can be transmitted by this method.

The only way to ensure that classified or sensitive information is secure and protected during transmission is for each of us to be aware of the problems involved and conscious of the fact that we must be continually alert to possible compromising situations. In selecting a mode of communication, we must be sure that it not only satisfies our needs for speed and/or convenience but, more important, provides the security that the information requires.

Exercises (007):

1. Which mode of transmission should never be used to transmit Secret information?

2. How can classified information be sent by radio securely?

3. State the advantages and disadvantages of transmitting information by messenger.

4. As what type of mail may Secret information may be sent through the US Postal Service?

008. Define "OPSEC" and indicate some of the precautions to take to ensure its effectiveness.

OPSEC. The operational security (OPSEC) program was recently implemented by the Joint Chiefs of Staff in an effort to combine communications security, physical security, transmission security, and administrative security. By combining these separate programs, our overall security program will become more effective. Under the new program, OPSEC teams will make periodic visits to each installation in an effort to point out areas of security weakness that people do not normally realize or notice. For example, stereotyped operations can be "dead giveaways" even though there are no actual security violations: thus, the fact that a unit is about to commit themselves may be deduced from increased radio communications activity, a phenomenon usually associated with increased mission activity. The teams' biggest job, however, is not identifying the weak areas, but determining ways to correct them. That latter determination takes the combined efforts of all of us. We must consider OPSEC in our daily work and examine everything that we do to identify OPSEC flaws, and to find ways to eliminate them.

Security Precautions. We have discussed some of the precautions that we can take to enhance our security program (e.g., don't leave a telephone receiver off the hook, use the appropriate mode of transmission, don't allow possibly sensitive actions to become stereotyped, etc., but now let's examine a few other actions and precautions that each of us should adhere to.

A big problem in security is the fact that people try to "talk around" sensitive subjects. In other words, they attempt to discuss the information over the phone or in insecure areas by implying their meaning rather than actually saying it; by so doing, they hope to disguise the information so that any unauthorized persons who might overhear it will not understand it. What they fail to realize is that if they can get their intended recipient to understand what they're talking about, a trained analyst would have little trouble deciphering it. Do *not* use "talking around" a subject as a means of transmitting information securely.

Another precaution to take is to never use "homemade" codes to disguise sensitive information. Such codes only succeed in bringing about confusion and at best slow down only slightly the time that it takes for someone else to decipher the code.

Also, refrain from discussing job-related or official information in insecure or public places. This practice is a trap that one can fall into all too easily. You might not consider your discussion as sensitive, but, as we said before, an enemy agent could put several bits of unclassified information together to get an insight into a classified operation.

Exercises (008):

1. What does "OPSEC" stand for?

2. Briefly state the main purpose of OPSEC.

3. What is meant by "talking around"?

4. One security precaution that you can take is never to "talk around" a sensitive matter in insecure circumstances. List two other precautions that you can take to ensure the security of sensitive information.

2-2. Property Accountability

In the Air Force, the amount of supplies and equipment in use each day is staggering. The job of trying to keep tabs on where all of these items are at any one time is even more overwhelming. However, it is imperative that we do just that if the Air Force is to operate within an ever-tightening budget. In this section, we shall discuss the supply system and some of the tools used to control and account for the supplies and equipment. We shall also discuss your responsibilities for supplies and some established procedures for recovering the cost of property losses.

009. State the purpose of the Air Force supply system and indicate how you, as a machinist, can help it to function efficiently.

Air Force Supply System. Stop and think for a minute of the number and types of equipment, material, and other supplies on hand within your shop. How did they all get there and where did they come from? Undoubtedly they were all purchased by the base supply unit at your base and were provided to your particular shop as they were needed. That is the purpose of the Air Force supply system: to provide not only your shop but *every* shop, office, and unit in the Air Force with the equipment, material, and supplies that it needs at the time that they are needed. It is a big job, as you can understand, but it doesn't end there. After the needed items have been delivered, they must be controlled, protected, and accounted for. To meet that requirement, the supply system includes established rules and regulations for maintaining records of supplies, for accounting for them, and for recouping losses due to negligence on the part of anyone using them.

As you can see, the task of any base supply unit is tremendous, but it isn't impossible if each of us helps. We can do this by taking care of Air Force equipment as if it were our own. And, in fact, it *is* ours: our taxes help pay for all of it. The more that is misused and abused, the more it costs the government, who gets its money from each one of us. Just think, for instance, of the quantity of numbered drill bits that supply must provide to your shop each year and then multiply that by the number of shops in the Air Force. If each person in those shops were to throw those bits away when they became dull, instead of resharpening them, the number of bits required would be tripled. That, of course, would cost thousands of *extra* dollars, yet such wasteful practices are not as uncommon as you might think. Think of the entire scope of the supply system and realize that every piece of equipment, from paper and pencils to aircraft, must be controlled, protected, and used wisely. Obviously, we, the users of these items, must do our part if supply is to accomplish its tremendous mission.

Exercises (009):

1. Where does an Air Force machine shop get tools and supplies from?

2. Briefly state the purpose of the Air Force supply system.

3. How can you as a machinist help the supply system operate efficiently?

010. Explain the use of supply condition tags.

Supply Condition Tags. There are three supply condition tags with which you should become familiar. These tags are DD forms in the 1500 series. They identify the condition of property.

Serviceable tag. DD Form 1574, Serviceable Tag—Material, is yellow. This tag is used on all new property, usable property to be turned in to supply, or property that has been repaired and can be used.

Unserviceable reparable tag. DD Form 1577-2, Unserviceable (Reparable) Tag—Material, is green and is used on property that can be repaired to a serviceable condition without exceeding 75 percent of the property's cost. It is used on equipment on which the repair action has been deferred for a period of time or on equipment that cannot be repaired at a particular location and must be forwarded to a depot-level facility for proper repair action. It is also used to identify property that is unserviceable only because some of its parts are missing. The reason for using the tag should be stated explicitly in the "Reason for Repairable Condition" block and the "remarks" block on the tag.

Unserviceable (condemned) tag. DD Form 1577, Unserviceable (Condemned) Tag—Material, is red. This tag is used on all property that cannot be repaired and on property on which the repair cost would exceed 75 percent of its value (the 75 percent rule is waived in the case of certain high-value items that are made of recoverable material). Any item that this tag is placed on should not be used for any reason.

Although you will probably be required to fill out these tags in accomplishing your job, most locations authorized only certain personnel within each shop to sign them. This is to ensure that Air Force guidelines and local directives are followed in determining the condition of the property or equipment.

Exercises (010):

1. List the form number and names of the three condition tags.

2. What does a red tag on a piece of equipment mean?

3. Which tag goes on a repaired piece of equipment?

4. Which tag goes on equipment to be repaired later?

011. Explain the usage of supply indexes and catalogs, and determine the proper forms to use for special requisitions, issues, and turn-ins.

There may be times when it will be necessary for you to do your own research for part numbers, stock numbers, source of supply, or types of tools, equipment, or materials. For this reason, you should have a basic understanding of how to use supply indexes and catalogs. (Usually, however, the supply research section in your base supply unit will do the researching for you.)

National Stock Number. The first thing that you must understand when talking about supply indexes and catalogs is the national stock number (NSN). The NSN for an item of supply consists of a four-digit Federal Supply Classification (FSC) code and a nine-digit national item identification number (NIIN). In the NSN 5110-00-234-6550, the first two digits (51) identify the major item group. There are presently 77 major groups, each of which contains items that are related by design, use, or some other way. The third and fourth digits together (10) designate a particular class within the major group. There are presently 604 classes within all 77 groups. The next two digits (00) signify that this number has been listed for some time. If this item were new in the supply listings, these two digits would read "01." The last seven digits are specific item identifiers.

Supply Indexes. Most of the indexes used by supply have been converted to microfilm cards that can be projected on a TV-type screen for reading. An entire volume can be contained on a few cards and can be scanned much faster than the old volume. For this study, however, we shall refer to them as books or handbooks.

Cataloging Handbook H2-1. This handbook gives the classification structure (groups and classes) of the FSC. All 77 groups are listed numerically and all the classes within each group are listed beneath the group number, along with the class title. For example, 51 is a group of items entitled "Handtools." Under the "51" group, we find all of the classes within it, such as 5110, Handtools, edged, nonpowered.

Cataloging Handbook H2-2. This handbook is the numeric index and lists all of the groups and classes numerically. It also contains an alphabetical listing of the entries included in each class.

Cataloging Handbook H2-3. This handbook is the alphabetical listing of the entries in the numeric index. You would use this book to determine the proper group and class if you had some idea of the correct name for an item.

Cross-reference indexes. C-RI-1 and C-RI-2 (both entitled "Master Cross-Reference Index") are used to find manufacturer's identification numbers and codes when the NSN is known or to find the NSN when the manufacturer's identification number is known.

S-2A-1 Index. This index lists USAF stock-lists (list of items within a group arranged numerically), Department of Defense Catalogs, and related cataloging publications.

Supply Catalogs. There are two main types of supply catalogs, the IL (identification list) and the ML (management data list). The IL consists of an alphabetical index, national stock number index, manufacturer's index, information table, and illustrations. It is used when an NSN is known, when descriptive data or dimensions are required, or when the name of the item is known and the NSN is required. The IL is contained in several volumes by FSC codes such as C5110-IL. The ML used to be in volumes much the same way, however, it is now one unit and has been converted to the microfilm cards. It is arranged in stock number sequence and contains such information as the item status, source category, and price.

Application. Now, let's see how you could research information about an item. Suppose you need the national stock number for a round file for filing 1/8" radii and you want a smooth, single cut surface. First the grope class must be determined by using the alphabetical index (H2-3) and looking under the listing "File, hand." Here you will find the class to be 5110, which you can easily convert to the proper IL, C5110-IL. Now you look in the alphabetical listing within C5110-IL to find "File, hand." Looking through the list of hand files, you will find one that closely fits your requirement; it is listed as:"File, hand, American Pattern; fig T294-W, RD Type: single cut, smooth cut face, .234 Dia: 6" long; Type XVI, Class 1, style C.GS/STD ref.666 F 325." The rest of the NSN is listed as 5110-00-234-6550. Notice that a figure reference is given. By turning to that figure in C5110-IL, you can check to be sure that you have the exact style or type of file that you want. Also, notice that the item is referenced to the General Services Administration Catalog (GS/STD ref.666 F 325)—which means that this item may be purchased through the General Services Administration (GSA). By turning to reference in this catalog, you can find the file as listed in C5110-IL, along with such information as the price and the number of files contained in a "standard pack" for shipping.

You can find similar information when you know only the NSN or only the manufacturer's part number by simply using the various applicable catalogs in much the same way. Therefore, we shall not go into detail for those cases. As we said previously, the supply research section will do this work for you. You have an oblication, however, to provide supply with as much information as possible about the item that you want. You will get much faster and more accurate results if you do so.

Special Requisitions, Issues, and Turn-Ins. There are several forms that are used to order various items from supply or to turn items back into supply. We shall briefly discuss three of them. Actual directions for filling them out may be found by consulting AFM 67-23, *Standard Base Supply Customer's Manual* (your shop custodian has a copy of this manual) and by consulting the base supply unit for local procedures.

AF Form 601b. Air Force Form 601b, Custodian Request/Receipt, is used to request issue or turn-in of certain shop property (property listed on the CA/CRL, Custodian Authorization/Custody Receipt Listing). This property consists of nonexpendable items such as shop machinery. The shop property custodian maintains the CA/CRL and will normally fill out the AF Forms 601b. AF Form 601b is used in conjunction with TAs (tables of allowance), which contain listings of authorized equipment for your shop. The tables of allowance are listed in AFR 0-10, Management Control and Authorization Program of Allowance Source Codes for USAF Activities. Forms 601b are processed through the EMO (equipment management office) to base supply for the issue or turn-in of property.

To accomplish a change in authorization, turn-in, or request issue of property, submit an AF Form 601b prepared in the number of copies required by the local EMO, and restrict the form to one item per form. Retain one copy in suspense and forward the remaining copies through the organization commander to EMO. Requests that are disapproved by the commander are not forwarded to EMO.

DD Form 1348-6. DD Form 1348-6, Non-NSN Requisition, is used when you need to purchase a part that does not have a national stock number. An item of this type must be obtained through "local purchase"; that is, base supply goes to the manufacturer or distributor and buys the item. Very detailed or accurate descriptions of the needed items are required when you are ordering items in this way.

AF Form 2005. AF Form 2005, Issue/Turn-in Request, is used to make initial requests for expendable items (certain repair parts, small drill bits, appexes, etc.). The supervisor directs the ordering of replacement parts and supplies, and he checks the AF Form 2005 for accuracy. The form is submitted to the demand processing unit, the bench stock unit, supply points, the individual equipment unit, or the base service store, depending on the expendable item required.

Exercises (011):

1. What two sets of numbers combine to make an NSN?

2. How many major item groups are there, and how are they represented in the NSNs?

3. Which index or handbook should you use to find out what type of items is contained in the "51" group of items?

4. Where would you find a listing of DOD Federal catalogs?

5. Which index might contain a picture or drawing of a required item?

6. What section of supply will aid you in translating a manufacturer's part number into an NSN?

7. Indicate the form to use for the following transactions.
   a. Purchase cleaning rags from the base service store.

   b. Request a change in property authorization.

   c. Issue of items listed on CRL.

   d. Local purchase of an item lacking an NSN.

012. Describe proper storage procedures for shop equipment and materials.

After you have received items from supply, you will normally have to store it or a portion of it for a period of time. You should understand a few simple rules concerning the storing of equipment and materials.

Equipment. In this discussion, "equipment" will refer to items used in the shop that are easily portable, such as tools, cutters and bits, and various machine attachments. For the sake of security, all equipment should be either in a lockable tool crib or room or in lockable cabinets. Items left lying around on machines or work tables invite theft. Items should never be stacked or stored on top of storage cabinets; not only is this practice insecure, but it is very dangerous, since opening or closing the cabinet might dislodge the item and cause it to fall and injure someone. Metal cutting tools should always be stored in such a way that the cutting edges are protected from contacting each other or other metal surfaces. For instance, they can be stored in wood-lined cabinets or drawers, hung on shadow boards with thin wood or plastic separators, or dipped in a hot-dip tank that coats the tool with a soft plastic-like substance. Also, you should protect machined and unpainted surfaces of tools and machine attachments with a thin film of a rust-preventive spray or oil. However, you should be careful not to coat areas of tools designed for hand gripping such as the handles of pliers, screwdrivers, hammers, etc; oily coatings on these areas might cause the tool to slip from your hand while you are using it.

Machine attachments should be stored in such a way that they are easily accessible. For instance, it would be dangerous as well as frustrating to remove a large milling machine vise from the back of a bottom cabinet shelf. An item of this type should be stored at approximately the average waist height in order to prevent injury during lifting. (When lifting very heavy objects, you should always seek help or use a hoist if one is available.)

Probably the most harped-on subject concerning shop equipment is cleanliness, which is extremely important for reasons other than just to please certain inspectors that appear in the shop periodically. A dirty piece of equipment will malfunction easily and, in the case of precision instruments, dirt will cause them to become inaccurate. You can imagine the consequences if they were used to take measurements for critical aircraft parts!

Material. We shall consider "materials" to mean such things as machine lubricants and metals and other materials used in the manufacture of various items. In the case of machine lubricants (oils and hydraulic fluids), bulk containers should be stored in an area outside the shop, in a shed or room specifically designed or modified for that purpose. Most organizations have oil storage sheds outside and away from the main work area because of the fire hazard they present. Small oil cans used for daily machine lubrication should be stored in a ventilated metal cabinet that has been grounded. Combustible materials, such as paper or cloth, should not be stored within or in close proximity to such a cabinet.

When you receive various shapes of metal rods and bars in the shop, they are normally delivered on a pallet or are just left lying on the floor. Either way, they become a dangerous stumbling block and they should be picked up as soon as possible. Make sure that the material is properly identified and marked (we shall discuss marking techniques in another chapter), and also be sure that long pieces are cut (unless the job calls for a full-length piece) so that they do not extend beyond the end of the rack. The same thing applies to other fabrication materials, such as various plastics and wood.

Exercises (012):

1. List the items that may be properly stored on top of shop cabinets.

2. Name the ways that the cutting edges of tools can be protected during storage.

3. What precaution should you observe when applying a rust-preventive substance to tools?

4. What is the ideal height for storing heavy machine attachments?

5. Where should a 5-gallon can of machine oil be stored?

6. Why should metal stock and other materials be picked up from the floor as soon as possible?

013. Indicate what is meant by "accountability" and "responsibility," and determine how each applies to Air Force personnel and property.

Air Force Regulation 67-10, *Responsibility for Management of Public Property in possession of the Air Force,* states the policies regarding responsibilities of property under the control of the Air Force. As members of the Air Force, we are responsible for property under our control. Along with *responsibility,* there is *accountability.* You should have a good understanding of each of these concepts.

Property *responsibility* is the obligation of an individual to properly care for any property under the control of the Air Force, whether it was receipted for or not, and whether or not it was issued to the individual's care, custody, or use. Property responsibility is in no way lessened if accountability has been terminated or if the person is not signed for or associated with a formal record account (CA/CRL).

Property *accountability* is the obligation imposed by law or regulation on a person for keeping accurate records of property. A person having this obligation may or may not have actual possession of the property.

The duty of taking care of the property that Uncle Sam has loaned to the Air Force is not to be taken lightly. We are *all* responsible for the protection and care of any and all equipment under the control of the Air Force. If you see someone abusing or misusing Air Force equipment, you have an obligation to report it to your superiors. You should also try to prevent possible damage to equipment by personally taking action or by reporting unsafe conditions. For instance, if you noticed a maintenance stand left on an aircraft parking ramp without having the brakes locked, you should either lock them yourself or report the situation to the aerospace ground equipment branch. Failure to do so might allow the stand to be blown into a parked aircraft, thereby causing expensive damage.

Accountability is a very real concern of the shop property custodian. He is the individual that we mentioned earlier who is receipted for the majority of the property in the shop. The CA/CRL lists all the property that the custodian is accountable for. In fact, when a custodian is transferred and must sign over the account to another person, if any item on the list is missing, the original custodian may be held liable; in other words, that individual might wind up paying for an expensive piece of equipment! Also, if the proposed custodian formally signs for the property on the list without checking to be sure that the property is physically in place, then he may become liable! Because you stand a good chance of becoming a property custodian during your stay in the Air Force, remember these facts. Don't be afraid of your custodial responsibility, but take the job seriously and be certain to check the CA/CRL over with personnel from the equipment management office (EMO) before you sign for the property on the list.

Exercises (013):

1. Which form of property obligation is concerned primarily with maintaining records? With care and safekeeping?

2. If Airman A noticed a pneumatic drill motor left by Airman B in the intake of an aircraft and did nothing about it, which airman would be responsible for any resulting loss or damage?

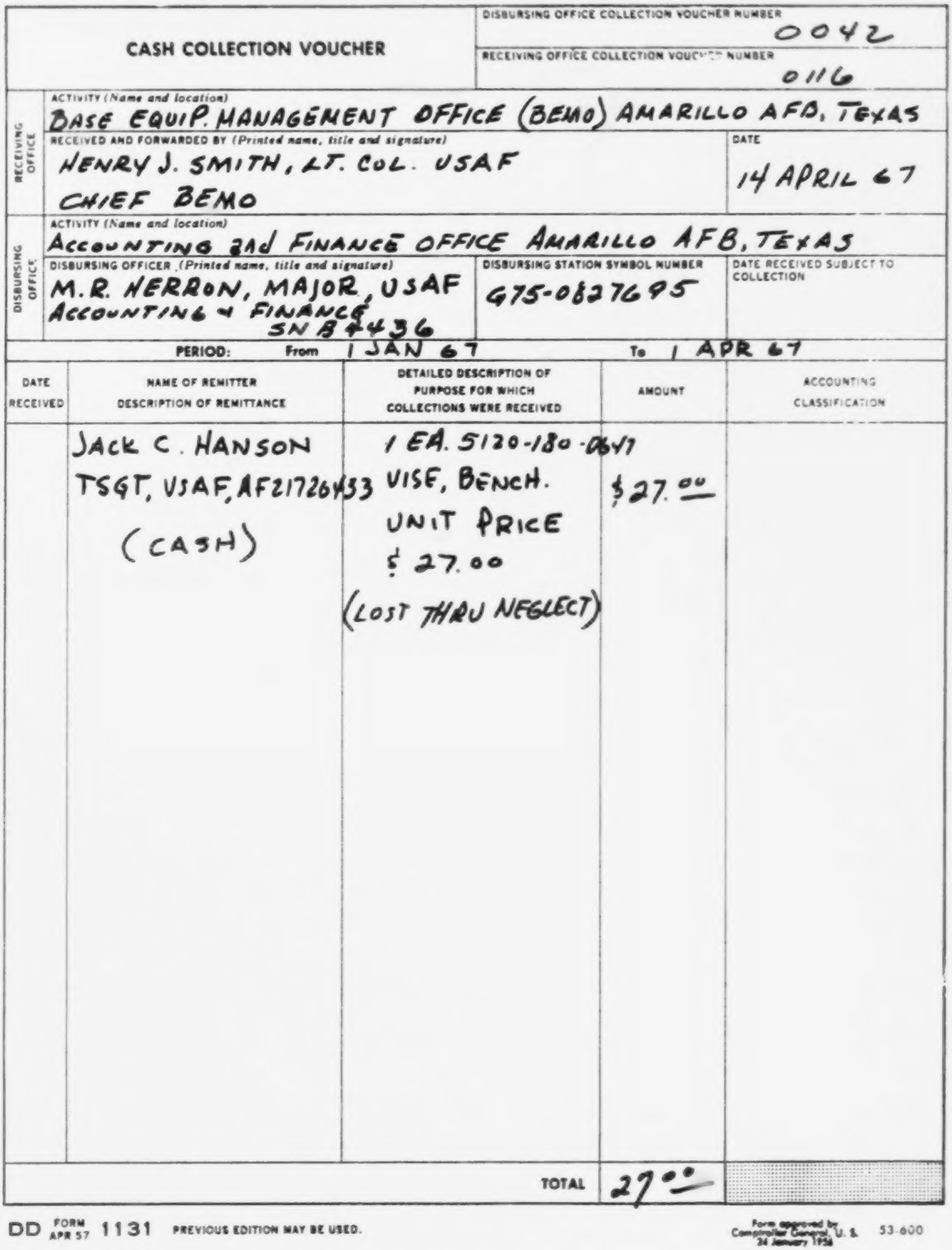
3. What very important action should you carry our when signing or receipting for property listed on a CA/CRL?

014. Indicate the purpose and uses of a cash collection voucher and a statement of charges.

Responsibility Relief. The monetary loss to the Air Force must be accounted for in some manner when property is lost, damaged, or destroyed. The person(s) with responsibility for the property must reimburse the Air Force. If not, the Air Force will stand the loss.

Two methods of being relieved of property responsibility involves the use of a cash collection voucher and a statement of charges. These two forms are used to reimburse the Air Force when pecuniary liability is admitted. The damage to the article or the list price of the article if the article is lost or destroyed, cannot exceed $250 to use these methods. Also, keep in mind that even though the individual has paid for the loss, the property does not become the property of the individual.

DD Form 1131. The least troublesome way to settle a monetary obligation is to pay in some form of cash. DD Form 1131, Cash Collection Voucher, is generally prepared by the responsible officer (or EMO) to cover the cash collections for a particular instance. Listed on the cash collection voucher (as shown in fig. 2-1) are the names of the airmen, the articles lost or damaged, and the amount involved. The voucher shows the complete Air Force description of the item involved and the purpose for which collection was made. Negligence and carelessness may be indicated as the causes of damage to the property. The statement "Used in Lieu of Report of Survey" is an indication that pecuniary liability has been admitted. Before the money is turned in



CASH COLLECTION VOUCHER

DISBURSING OFFICE COLLECTION VOUCHER NUMBER: 0042

RECEIVING OFFICE COLLECTION VOUCHER NUMBER: 0116

RECEIVING OFFICE

ACTIVITY (Name and location): BASE EQUIP. MANAGEMENT OFFICE (BEMO) AMARILLO AFB, TEXAS

RECEIVED AND FORWARDED BY (Printed name, title and signature): HENRY J. SMITH, LT. COL. USAF
CHIEF BEMO

DATE: 14 APRIL 67

DISBURSING OFFICE

ACTIVITY (Name and location): ACCOUNTING and FINANCE OFFICE AMARILLO AFB, TEXAS

DISBURSING OFFICER (Printed name, title and signature): M.R. HERRON, MAJOR, USAF
ACCOUNTING & FINANCE
SN B4436

DISBURSING STATION SYMBOL NUMBER: G75-0827695

DATE RECEIVED SUBJECT TO COLLECTION:

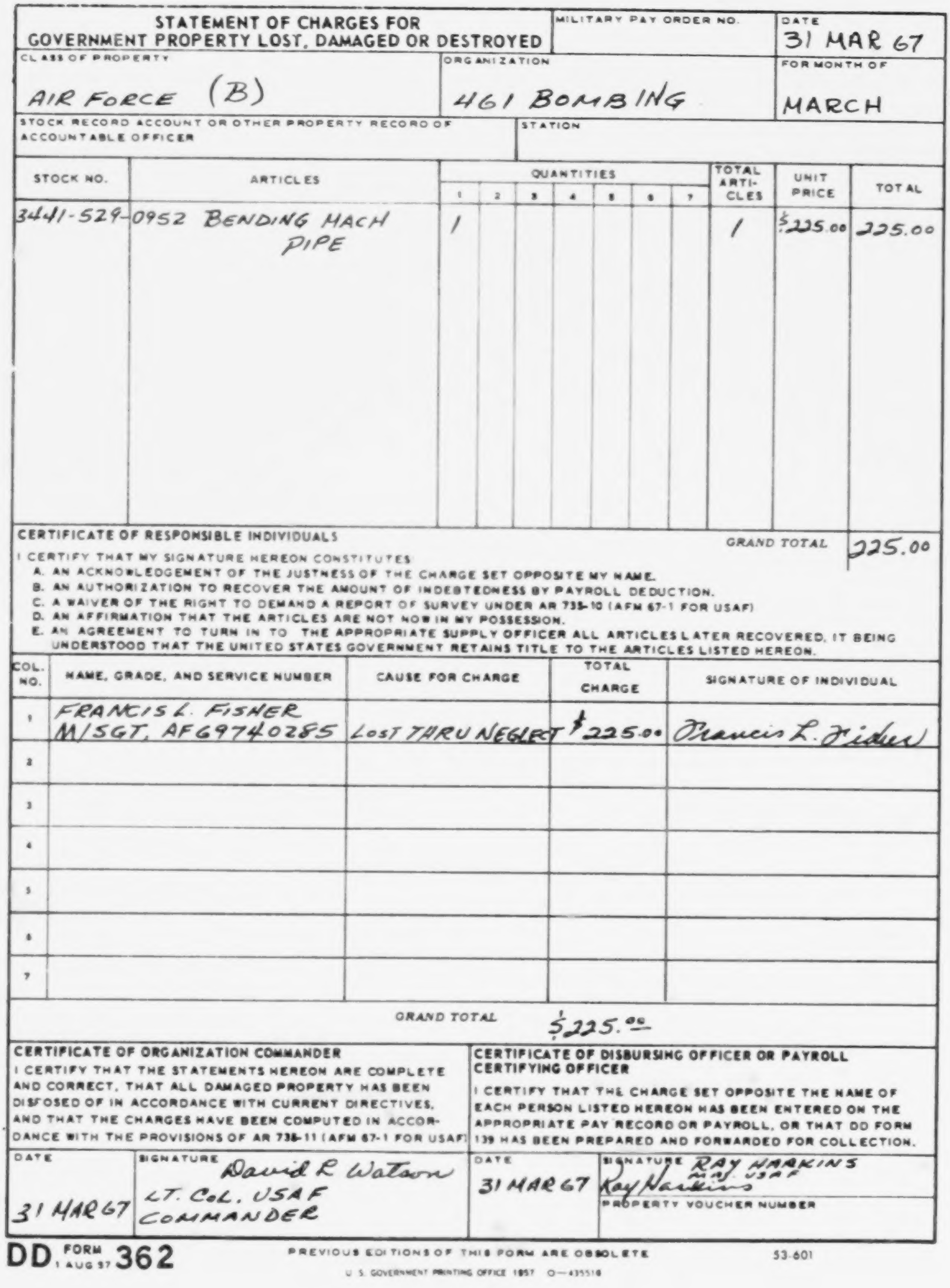
PERIOD: From 1 JAN 67 To 1 APR 67

DATE RECEIVED	NAME OF REMITTER DESCRIPTION OF REMITTANCE	DETAILED DESCRIPTION OF PURPOSE FOR WHICH COLLECTIONS WERE RECEIVED	AMOUNT	ACCOUNTING CLASSIFICATION
	JACK C. HANSON TSGT, USAF, AF21726433 (CASH)	1 EA. 5120-180-0647 VISE, BENCH. UNIT PRICE $27.00 (LOST THRU NEGLECT)	$27.00	
		TOTAL	27.00	

DD FORM APR 57 1131 PREVIOUS EDITION MAY BE USED.

Form approved by Comptroller General, U. S. 24 January 1956 53-600

Figure 2-1. Cash collection voucher.



STATEMENT OF CHARGES FOR GOVERNMENT PROPERTY LOST, DAMAGED OR DESTROYED

MILITARY PAY ORDER NO.

DATE: 31 MAR 67

CLASS OF PROPERTY: AIR FORCE (B)

ORGANIZATION: 461 BOMBING

FOR MONTH OF: MARCH

STOCK RECORD ACCOUNT OR OTHER PROPERTY RECORD OF ACCOUNTABLE OFFICER:

STATION:

STOCK NO.	ARTICLES	QUANTITIES 1	2	3	4	5	6	7	TOTAL ARTICLES	UNIT PRICE	TOTAL
3441-529-0952	BENDING MACH PIPE	1							1	$225.00	225.00

GRAND TOTAL: 225.00

CERTIFICATE OF RESPONSIBLE INDIVIDUALS

I CERTIFY THAT MY SIGNATURE HEREON CONSTITUTES:

A. AN ACKNOWLEDGEMENT OF THE JUSTNESS OF THE CHARGE SET OPPOSITE MY NAME.
B. AN AUTHORIZATION TO RECOVER THE AMOUNT OF INDEBTEDNESS BY PAYROLL DEDUCTION.
C. A WAIVER OF THE RIGHT TO DEMAND A REPORT OF SURVEY UNDER AR 735-10 (AFM 67-1 FOR USAF)
D. AN AFFIRMATION THAT THE ARTICLES ARE NOT NOW IN MY POSSESSION.
E. AN AGREEMENT TO TURN IN TO THE APPROPRIATE SUPPLY OFFICER ALL ARTICLES LATER RECOVERED, IT BEING UNDERSTOOD THAT THE UNITED STATES GOVERNMENT RETAINS TITLE TO THE ARTICLES LISTED HEREON.

COL. NO.	NAME, GRADE, AND SERVICE NUMBER	CAUSE FOR CHARGE	TOTAL CHARGE	SIGNATURE OF INDIVIDUAL
1	FRANCIS L. FISHER M/SGT. AF69740285	LOST THRU NEGLECT	$225.00	Francis L. Fisher
2				
3				
4				
5				
6				
7				

GRAND TOTAL: $225.00

CERTIFICATE OF ORGANIZATION COMMANDER

I CERTIFY THAT THE STATEMENTS HEREON ARE COMPLETE AND CORRECT, THAT ALL DAMAGED PROPERTY HAS BEEN DISPOSED OF IN ACCORDANCE WITH CURRENT DIRECTIVES, AND THAT THE CHARGES HAVE BEEN COMPUTED IN ACCORDANCE WITH THE PROVISIONS OF AR 735-11 (AFM 67-1 FOR USAF)

DATE: 31 MAR 67

SIGNATURE: David R Watson
LT. COL. USAF
COMMANDER

CERTIFICATE OF DISBURSING OFFICER OR PAYROLL CERTIFYING OFFICER

I CERTIFY THAT THE CHARGE SET OPPOSITE THE NAME OF EACH PERSON LISTED HEREON HAS BEEN ENTERED ON THE APPROPRIATE PAY RECORD OR PAYROLL, OR THAT DD FORM 139 HAS BEEN PREPARED AND FORWARDED FOR COLLECTION.

DATE: 31 MAR 67

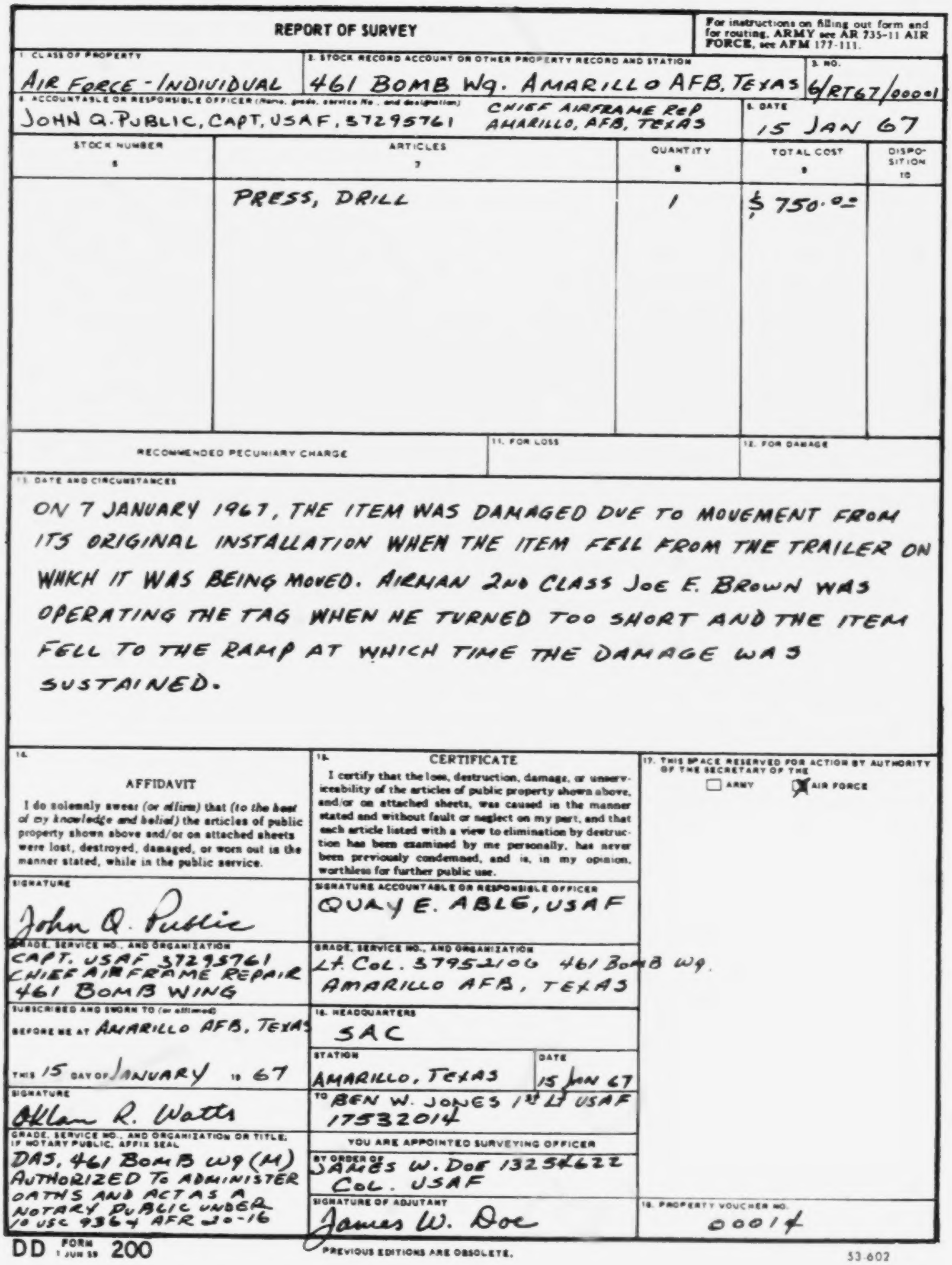
SIGNATURE: RAY HAAKINS
MAJ. USAF
Ray Haakins

PROPERTY VOUCHER NUMBER:

DD FORM 1 AUG 57 362 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE — 53-601

U. S. GOVERNMENT PRINTING OFFICE 1957 O—435510

Figure 2-2. Statement of charges.



REPORT OF SUYEY

For instructions on filling out form and for routing, ARMY see AR 735-11 AIR FORCE, see AFM 177-111.

1. CLASS OF PROPERTY: AIR FORCE - INDIVIDUAL

2. STOCK RECORD ACCOUNT OR OTHER PROPERTY RECORD AND STATION: 461 BOMB Wg. AMARILLO AFB, TEXAS

3. NO.: 6/RT67/00001

4. ACCOUNTABLE OR RESPONSIBLE OFFICER (Name, grade, service No., and designation): JOHN Q. PUBLIC, CAPT, USAF, 37295761 CHIEF AIRFRAME REP AMARILLO, AFB, TEXAS

5. DATE: 15 JAN 67

STOCK NUMBER 6	ARTICLES 7	QUANTITY 8	TOTAL COST 9	DISPOSITION 10
	PRESS, DRILL	1	$ 750.00	

RECOMMENDED PECUNIARY CHARGE

11. FOR LOSS

12. FOR DAMAGE

13. DATE AND CIRCUMSTANCES

ON 7 JANUARY 1967, THE ITEM WAS DAMAGED DUE TO MOVEMENT FROM ITS ORIGINAL INSTALLATION WHEN THE ITEM FELL FROM THE TRAILER ON WHICH IT WAS BEING MOVED. AIRMAN 2ND CLASS JOE E. BROWN WAS OPERATING THE TAG WHEN HE TURNED TOO SHORT AND THE ITEM FELL TO THE RAMP AT WHICH TIME THE DAMAGE WAS SUSTAINED.

14. **AFFIDAVIT**

I do solemnly swear *(or affirm)* that *(to the best of my knowledge and belief)* the articles of public property shown above and/or on attached sheets were lost, destroyed, damaged, or worn out in the manner stated, while in the public service.

SIGNATURE: John Q. Public

GRADE, SERVICE NO., AND ORGANIZATION: CAPT. USAF 37295761 CHIEF AIRFRAME REPAIR 461 BOMB WING

SUBSCRIBED AND SWORN TO (or affirmed) BEFORE ME AT AMARILLO AFB, TEXAS

THIS 15 DAY OF JANUARY 19 67

SIGNATURE: Allan R. Watts

GRADE, SERVICE NO., AND ORGANIZATION OR TITLE; IF NOTARY PUBLIC, AFFIX SEAL: DAS, 461 BOMB Wg (M) AUTHORIZED TO ADMINISTER OATHS AND ACT AS A NOTARY PUBLIC UNDER 10 USC 9364 AFR 30-16

15. **CERTIFICATE**

I certify that the loss, destruction, damage, or unserviceability of the articles of public property shown above, and/or on attached sheets, was caused in the manner stated and without fault or neglect on my part, and that each article listed with a view to elimination by destruction has been examined by me personally, has never been previously condemned, and is, in my opinion, worthless for further public use.

SIGNATURE ACCOUNTABLE OR RESPONSIBLE OFFICER: QUAY E. ABLE, USAF

GRADE, SERVICE NO., AND ORGANIZATION: Lt. Col. 37952106 461 BOMB Wg. AMARILLO AFB, TEXAS

16. HEADQUARTERS: SAC

STATION: AMARILLO, TEXAS

DATE: 15 JAN 67

TO BEN W. JONES 1st Lt USAF 17532014

YOU ARE APPOINTED SURVEYING OFFICER

BY ORDER OF JAMES W. DOE 13254622 COL. USAF

SIGNATURE OF ADJUTANT: James W. Doe

17. THIS SPACE RESERVED FOR ACTION BY AUTHORITY OF THE SECRETARY OF THE ☐ ARMY ☒ AIR FORCE

18. PROPERTY VOUCHER NO.: 00014

DD FORM 1 JUN 59 200

PREVIOUS EDITIONS ARE OBSOLETE.

53-602

Figure 2-3. Report of survey.

to the finance office, the cash collection voucher must be approved by the individual's commander.

DD Form 362. Airman and civilian employees use the DD Form 362, Statement of Charges for Government Property Lost, Damaged, or Destroyed, as shown in figure 2-2, when pecuniary liability is admitted but payroll deduction is desired instead of a cash payment. The price of the damaged items cannon exceed $250. The individual is charged the cost of the articles or is allowed up to 25 percent depreciation. For this reason, the actual cost may be less than the prices listed in the top section of the form. When the individual signs a statement of charges, he has made an acknowledgement, an authorization, a waiver of a right, an affirmation, and an agreement. The commander must certify this form before it is submitted for a payroll deduction. Officers who admit liability use DD Form 114, Military Pay Order, to authorize payroll deductions instead of the statement of charges.

Exercises (014):

1. What is the maximum property value or repair cost for which a cash collection voucher or statement of charges may be used?

2. What condition would necessitate the use of a statement of charges instead of a cash collection voucher?

3. Explain why there might be a price of $200 listed at the top of a statement of charges form and a $185 price listed at the bottom.

015. State the purpose of the report of survey, tell who prepares it, and indicate when it must be initiated.

Report of Survey. A report of survey is an instrument for explaining and recording the circumstances that involve loss, damage, or destruction of the Air Force property. When used, it supports the dropping of property from the records. It also serves to resolve the questions of responsibility for loss and it fixes liability. In summary, when one individual will not admit liability or when the amount to be charged is over $250, a report must be prepared on DD Form 200, Report of Survey, shown in figure 2-3.

Preparing the report of survey form is the first step in the report of survey process. The individual who has custodial responsibility for the property starts the process. A provision has been made for others to perform this duty for him, but this provision is applied only when it is impractical for the custodian to fill out the form. Since the report of survey is a means for explaining the loss, damage, or destruction of Government property, the responsible individuals should include all pertinent facts and circumstances surrounding the loss. Remember, the information presented on the report of survey is the basis for deciding whether an investigation is necessary. It is important that reports of survey be initiated and processed within 30 days of the time the loss was discovered. The investigation must be made while the persons involved, including witnesses, are available and facts are still fresh. After the report is complete, it goes to the base appointing authority for review and appropriate action.

If the report of survey is approved, the individual will be relieved of the responsibility of the individual equipment. He need not reimburse the Air Force for the cost of the item. However, if the authorities decide that the individual was negligent, he will have to reimburse the Air Force.

Exercises (015):

1. What is the purpose of the report of survey?

2. Who prepares a report of survey?

3. A report of survey must be prepared within what time period after the loss is discovered?

CHAPTER 3

Shop and Flight Line Safety

YOU HAVE PROBABLY heard people say that you can tell a machinist by looking at his hands: there is usually a finger or two missing! Well, that is happily not so much the rule today, but it does bring out a good point. One of the reasons that missing fingers were numerous among machinists in times past was that safety standards were not properly set and were not followed or enforced to any great degree. It seems that people would rather learn the importance of a safety practice or standard the hard way than take comeone's advice. Of course, that tendency is still with us, but it has been nullified to a great degree in the Air Force by knowledgeable supervisors. They enforce the safety standards that the Air Force has compiled from years of experience. We shall discuss some of those standards and practices in this chapter. We shall look at shop and flight line safety precautions and also explain what to do in case there is an accident. Read carefully and don't choose the old-fashioned way to learn safety—it hurts!

3-1. Shop Safety

In this section, we shall look at some shop safety precautions, including fire prevention practices. These are by no means the only safety practices or standards to observe. An entire regulation, AFR 127-101, *Accident Prevention Handbook*, is devoted to familiarizing Air Force personnel with safety practices and standards. We shall touch briefly on several aspects of safety, but you should take it upon yourself to become personally familiar with AFR 127-101.

016. Explain various safety precautions and practices pertaining to in-shop operations.

Clothing and Protective Equipment. As a machinist, you are exposed to many health hazards every day. Such things as flying metal chips, sharp edges of tools and work, and slippery surfaces caused by lubricants and coolants are safety hazards that are just waiting for someone to let his guard down just for a second. And a second is all that it takes to lose an eye, sever a finger, smash a foot, or worse. The Air Force issues equipment to help protect you against these hazards, but they won't do any good if you don't use them. Let's review some of those items.

Your eyes are one of your most priceless possessions—priceless because man has not yet learned how to replace them. When you think about this fact, you should agree that the slight inconvenience caused by wearing safety glasses or goggles is a small price indeed to pay for eye protection. Safety glasses or goggles should be worn any time that you are around machinery in operation, including handtools, whether powered or nonpowered. Many shops require eye protection to be worn at all times in the shop area. This requirement is an excellent measure, but don't forget those protectors when you go to other shops; the dangers are *not* confined to machine shops alone. If you wear safety glasses instead of goggles, you should be sure to use the side guards normally provided. They can be ordered through supply from the GSA catalog and they will more than double the protection of your glasses. Also, when you use any type of grinding equipment, put a full face shield on. As you know, grinding wheels cut out chips of metal no bigger than dust particles. The problem is that they are usually propelled many directions at once. And if they should get into your eye, they are very difficult to remove and, in the case of steel chips, will quickly spread rust particles around your eye. Rust particles usually require an eye operation to remove them completely.

Another item of protection that draws a lot of criticism is safety-toe boots. Granted, they are not the most comfortable shoes that you can wear, but they do offer outstanding foot protection. And they are a thousand times more comfortable than a cast! As we indicated before, experience gained over the years has proven their worth. As a machinist, you are going to be handling heavy metal objects almost daily. A 25-pound lathe chuck can knock a big chunk out of a solid concrete floor when dropped from waist heights; don't be silly enough to think that an unprotected foot would fair any better than concrete! Wear your safety boots—you'll get used to them sooner than you think.

Have you ever started to pick up a heavy object and found a burr or sharp edge right where you put your hand? Most of us have and, in most cases, we came away with a cut or scratched hand and a few choice words. This situation can be easily avoided by simply putting on a pair of pigskin gloves *before* attempting to lift heavy objects. Again, the Air Force will furnish the gloves if you want them, so take advantage of the offer.

There are several items that are more protective when they are *not* worn. To prevent getting caught in machines, *don't* wear the following items: loose-fitting jackets, unbuttoned sleeves, ties, finger rings of any kind, bracelets, necklaces, key chains or wristwatches. These items can cause you to lose a finger, hand, or worse, if they should get caught in a piece of machinery.

Machine Operator Safety. To protect yourself from injury while operating shop equipment, there are several simple things that you can do other than wearing protective clothing, and avoiding unsafe apparel. For instance, by simply buttoning your shirt collar button, you can protect your lower neck and chest from a very aggravating and painful injury: a red-hot metal chip dropping down the inside of your shirt! The bad part of this type of injury is that while you are jumping around trying to keep the chip from resting on your skin, you are setting yourself up for a much more disastrous accident—like falling into a revolving lathe chuck!

One of the most important things that you should do as a machine operator is to check the machine over before operating it. Check those machine guards and cowls. They were put there to protect you from moving parts like belts, pulleys, gears, and etc., but they won't do any good if they are left lying beside the machine. Also, physically check the location of the shutoff switch or button, even if you're familiar with the particular type of machine. Quickly plan, in your mind, how you will get to that switch in an emergency. It is difficult to *look for* a shutoff switch when you're trying to dodge a big hunk of steel that pulled loose during a drill press operation!

When you are producing metal chips during a machine operation, don't remove them with your hands—even with gloves on. They are extremely sharp, are usually hot, and can catch in the machine and be dragged through your hands before you can turn loose. Needless to say, they can cause *severe* injuries, so take an extra minute and shut the machine off before you handle them, and then use a chippan and brush instead of your hands.

Another good habit to get into is to concern yourself with cleanliness. Much loss of time and pain can be avoided if you keep yourself and your work area clean and orderly. Floors should always be kept free of obstructions or liquid spillage. Obstructions can be raw stock, chips from a machining operation, or tools. Liquid spills should be wiped up as soon as possible.

Some units that you disassemble have small parts that can be easily lost, broken, or mixed with other parts. To avoid loss of time while you hunt for another part, keep your bench top in a neat and orderly condition. A cluttered bench makes effective work almost impossible and can cause accidents. Dispose of wornout parts promptly.

Finally, keep your attention focused on what you're doing. When you are operating a machine, it deserves your total concentration. If you must converse with someone, shut the machine off first. Many injuries have been caused and many parts have been made a second time because an operator was trying to divide his attention between the machining operation and a talkative buddy.

Exercises (016):

1. List three safety hazards that a machinist is confronted with daily.

2. Why are a person's eyes considered one of his most priceless possessions?

3. List some of the items that the Air Force furnishes to help protect the machinist from various hazards.

4. Why does a grinding operation require more than just a pair of safety glasses for adequate protection?

5. What items should *not* be worn around the shop area?

6. What is one of the first and most important things that you should do before operating a milling machine?

7. Why shouldn't you try to talk with someone while you are operating a machine?

017. Describe fire preventive measures required for machine shop operations and the procedures to follow if a fire does occur.

Fire Prevention. Fire prevention cannot be overemphasized, since the Air Force loses millions of dollars every year in accidental fires. Most of these fires are caused by carelessness in disposing of combustible materials, such as oily rags and smoking materials—this is the main reason that smoking is not permitted within 50 feet of parked aircraft, hangars, shops, or any building where flammable liquids are stored or being used.

All combustible materials, including clean rags, should be placed in covered metal containers. Soiled rags should go into a metal container that has a self-closing lid. They should not be mixed with any other type of waste. These precautionary practices are necessary in order to prevent spontaneous conbustion, which can occur at any time.

Also, as we mentioned in a previous chapter, bulk oil and paint containers should never be stored in the shop. They belong in a metal locker or properly constructed building at least 50 feet from other buildings in the area. Of course, no smoking is allowed within 50 feet of a building of this type.

Overloaded electrical outlets and defective circuit breakers are also fire hazards: keep this in mind whenever you plug in an electrically powered tool or piece of equipment.

Here are a few additional precautions that you should observe; you can add to the list from your own experience.

- Observe the signs in all NO SMOKING areas.
- Do not allow your clothing to become saturated with fuel or oil. If they do, change your clothing and wash yourself as soon as possible.
- Do not store gasoline, kerosene, jet fuel, or any other flammable liquids in open containers.
- Always make sure that the static lines are in place and that the aircraft is grounded properly before you work on an aircraft.
- Do not put cigarettes or matches in a wastebasket even if they appear to be out.
- Do not open any oxygen valve near a flame or a lighted cigarette

Fire Fighting. If fires do occur (and some will, no matter how many precautions are taken), you must be ready to fight them quickly and effectively. You should know the telephone number of the base fire department, the location of the fire extinguishers, and which type of extinguisher to use for the type of fire that you are fighting.

The telephone number of the base fire department is usually posted in large figures on posters in the shop, in the barracks, and on the flight line. As a rule, the base telephone directory has this number printed in large figures on the cover page or on one of the first pages of the book. If alarm boxes are installed on your base, learn where they are and how to use them.

Fire extinguishers look alike. Don't use the wrong type of extinguisher, as it can make the fire worse. Every shop should have a least two types of fire extinguishers: the carbon dioxide (CO2) type and the water type. It is a good idea for all workers to become familiar with their correct use. Water-type fire extinguishers should be used for paper, textile, and wood fires. If a fire should result from an electrical breakdown, use a chlorobromomethane (CBM) (if available) or carbon dioxide extinguisher to fight it. If the fire is in a close place, always use the carbon dioxide type, since CBM extinguishers emit very dangerous fumes. The carbon dioxide extinguishers should also be used on oil, grease, and paint fires. Other types of extinguishers are *not* suitable for fighting this type of fire.

One of the most important things to remember if a fire should break out is to be sure that the fire department is notified immediately, no matter how small the fire. You should fight the fire if you can, but it can be a disastrous mistake to try to take the place of trained firefighters. Much property damage, serious injuries, and even fatalities can occur when people try to extinguish fires by themselves without calling the fire department. By the time they realize that they can't handle the fire, it is too often to late for them, the property, or both!

Exercises (017):

1. Why is a 50-foot NO SMOKING area established around areas where flammalbe liquids are in use?
2. How should soiled rags be contained while in a shop?
3. What type of extinguisher should be used on electrical fires?
4. What should be used on a magnesium or titanium fire?
5. What action is essential whenever a fire occurs?

3-2. Flight Line Safety

Too often, safety is forgotten when a machinist heads for the flight line. There are several reasons (inexcusable though they may be) for this: there is usually no supervisor around to enforce safety standards, the machinist is usually pressured to complete line work quickly, weather conditions make extended staty time uncomfortable, etc. The flight line can either be one of the most dangerous places in the world or one of the safest, depending entirely on how you and other observe established safety precautions and practices. Let's review some of those precautions.

018. Describe hazards and state safety precautions pertaining to flight line operations.

Clothing and Protective Equipment. The Air Force has developed protective clothing and equipment for flight line operations based, again, on years of experience. Probably the most important pieces of this equipment are earplugs and muffs. A person's ears can be permanently damaged much easier than most people think. Working around an operating jet engine or certain turbine and gas-powered pieces of aerospace ground equipment (AGE) without ear protection can easily cause gradual damage to a person's ears without the person's realizing it until it's too late. You should have earplugs and/or muffs *every* time that you go to the flight line. Be sure to wear them.

Bases in colder climates have a special hazard to contend with during the winter months: cold temperatures! In these areas, you should wear the extra winter gear that is provided. Granted, it is usually bulky and prevents the freedom of movement that you are normally used to, but it's much better to do the job a little slower than to go back to the shop with frostbitten ears, fingers, or toes. Frostbite is extremely painful and can result in amputation of the affected area.

Hot climates also have certain weather hazards. When the temperature soars to 90° and above, metal surfaces on the flight line become much too hot to touch. If you must work on top of an aircraft under these circumstances, you should always sit or kneel on a padded cushion instead of the metal surface. Aircraft surfaces can become so hot that even prolonged standing on them is impossible. Also, the possiblility of sunburn and heatstroke is greatly increased due to the fact that the heat is radiated off the surface as well as directly from the sun. This is no place to try to get a suntan; keep that shirt on! It may be uncomfortable, but it will keep you from suffering a painful burn. Take short breaks periodically and get into some shade to prevent sunstroke.

Aircraft and Equipment Hazards. The temperature and velocity of the exhaust gases behind an operating jet engine are great enough to cause serious injury. The temperature of the exhaust gases 25 feet behind one of the smallest engines, the J-69, installed in the T-37 training aircraft, exceeds 350° F. The velocity of the exhaust gases is another hazard. As a general rule, the minimum safe distance behind an operating engine is 200 feet; for the F-4, it is 250 feet. Blast fences help reduce the safe distance. A jet engine uses a large volume of air. All of this air is taken into the intake. The suction developed immediately in front of the engine is enough to pull caps, coats, or men into the engine. The minimum safe distance in front of the engine is 25 feet. Do not approach closer than 5 feet to the duct entrances from the side or rear. All objects must be removed from the area in front of the ducts before the engine is started.

The area in line with the plane of rotation of the turbine wheel must be kept clear. If a wheel should suddenly disintegrate when the engine is running, the pieces can be thrown a long distance. Standing directly in line with a turbine wheel is like looking down the barrel of a loaded and cocked rifle. The same precautions apply to the turbine wheels of pneumatic or combustion (fuel-air) starters. They turn at a very high rate of speed and are extremely dangerous. The turbine wheel danger area of the later model jet engines and turboprop engines are much larger, since they use multistage turbine wheels.

Turboprop engines are used on some of the cargo aircraft, such as the C-130. The propellar is dangerous if proper precautions are not observed. Many persons have been seriously hurt or killed by propellers. The main reason for these injuries is that propellers become almost invisible during run-up operations. People walk into them without ever seeing them!

As we stated before, the high-frequency sound of modern jet engines can cause you to become completely deaf. It can also cause severe mental health damage. Prolonged exposure to this noise can cause nervous tension to build up to the breaking point (another excellent reason to wear those earplugs!). The noise level of a 5,00-pound thrust turbojet engine can cause pain. A larger turbojet with afterburner can cause not only pain but physiological symptoms. A good example of high noise level is the F-4 aircraft, which uses the 15,000-pound thrust J-79 engine. The danger area extends over 1,600 feet behind the aircraft as well as sizable distances in front of and to the side of it.

Most hazards can be avoided by simply paying attention to what you are doing. Remember, most accidents are caused by carelessness. Here are a few other flight line precautions:

a. Install guard rails, especially on high stands.

b. Install the safety pins on all hydraulically operated work stands before you use the stands.

c. Keep tools in your box when not in use. A loose tool on a stand can cause a serious fall.

d. Do not place toolboxes in a position where they can fall and hurt someone.

e. Be careful working around the trailing edges of the wing and control surfaces. These edges are sharp. The leading edge of the wing on some aircraft, such as the T-38, is just as sharp.

f. Do not work in the flap or speed brake area until you are sure that these controls cannot be operated.

g. Be sure that the aircraft static grounds are installed and in good condition.

h. Do not wear jewelry or a wristwatch while you are working. They can catch on sharp surfaces and seriously injure you.

i. When operating pneumatic equipment on the flight line, be sure that the air pressure in the lines does not exceed 150 psi. Never hook into a high-low stage compressor (high-pack) to operate pneumatic tools: a malfunction in the unit could release enough air pressure to literally explode the tool in your face or rupture the hose, causing it to whip wildly. Use only the single-stage compressor (low-pack) and check the pressure setting.

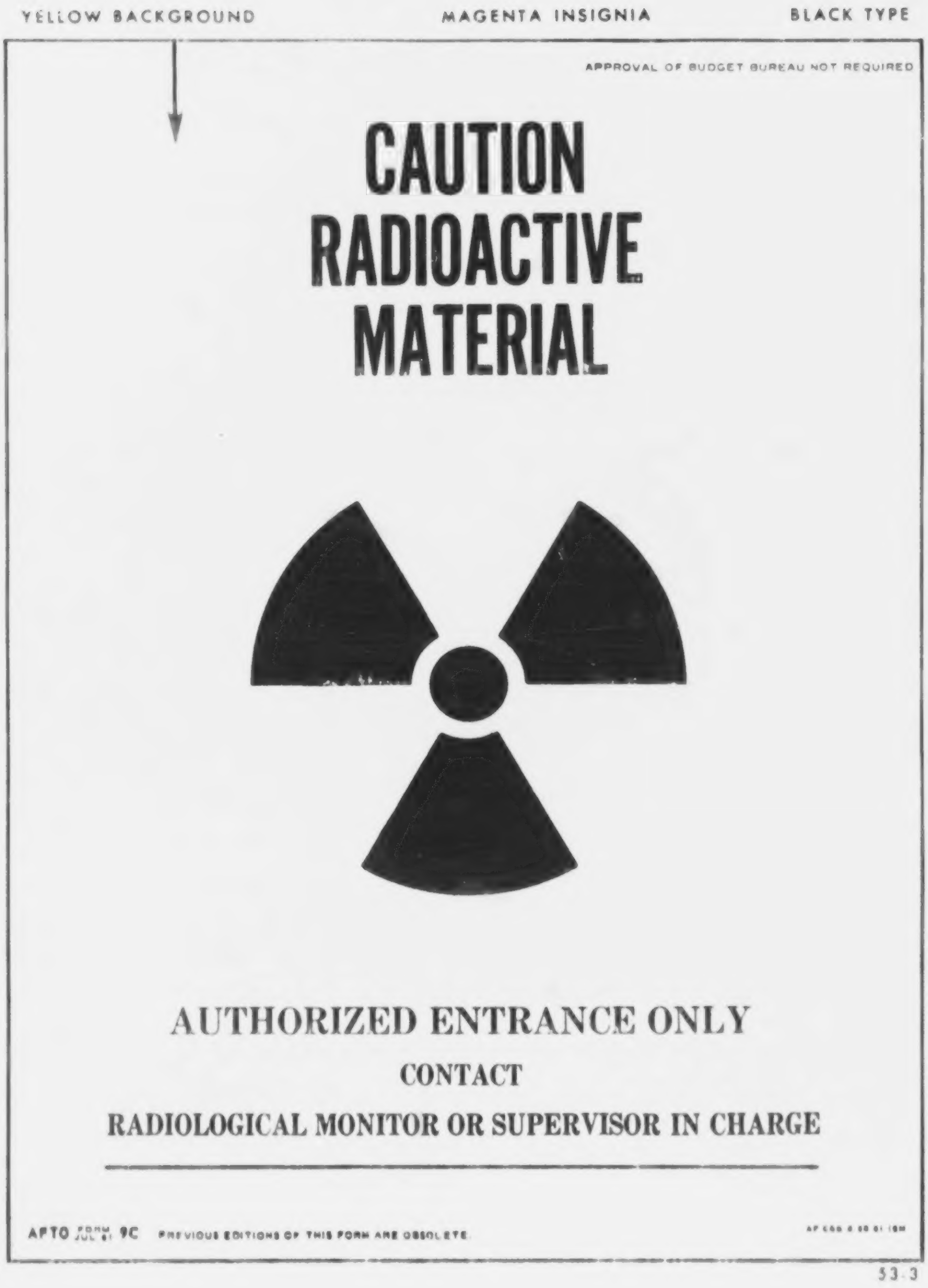
Radiation Hazards. Because of the new sophisticated materials used in aircraft and certain specialized metal inspection techniques, the problem of radiation exposure is becoming more pronounced each day. Radiation is such a serious health hazard that elaborate precautions are taken in the Air Force to guard against even accidental exposure. Since you cannot see radioactivity, several hours may elapse after exposure before you feel any effects; therefore, you must be able to (placard, 8½ x 11 inches). These placards are posted in conspicuous places. They indicate that the radiation intensity in the area exceeds one milliroentgen hours (mr/hr) but is less than 100 mr/hr.

- AFTO Form 9B, Radioactive Material Warning (label). This is a flexible but durable gummed label. A sufficient number of labels are attached to insure that one is visible from any direction of approach.
- AFTO Form 9C, Caution Radioactive instantly recognize radiation warnings. The primary purpose of the various AFTO Form 9 warning signs is to guard against gamma radiation.

Figure 3-1 shows one of the radiation warning placards. All radiation signs display the distinctive three-bladed magenta-colored insignia against a yellow background with black block type. The warning signs are designed to attract immediate attention. Each sign is designed for a specific purpose, and the exact size for most of them is specified by technical order. The AFTO 9 series forms are listed below:

- AFTO Form 9, Caution Radiation Area Material (placard, 8½ x 11 inches). This placard identifies an area in which radioactive materials are stored.

BEST COPY AVAILABLE


YELLOW BACKGROUND
MAGENTA INSIGNIA
BLACK TYPE

APPROVAL OF BUDGET BUREAU NOT REQUIRED

CAUTION
RADIOACTIVE
MATERIAL

AUTHORIZED ENTRANCE ONLY

CONTACT

RADIOLOGICAL MONITOR OR SUPERVISOR IN CHARGE

AFTO FORM JUL 61 9C PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

53-3

Figure 3-1. Radiation warning placard.

- AFTO Form 9D, Radiation Ingestion Hazard (placard, 8½ x 11 inches). This placard warns against eating, drinking, or smoking in the area. It is displayed as directed by the base medical service.
- AFTO Form 9E, High Radiation Area Warning (placard, 18 x 24 inches). This placard identifies an area in which the radiation intensity exceeds 100 mr/hr.
- AFTO Form 9F, Airborne Radioactivity

Area Warning (placard). The use of this placard is directed by the base medical service when radioactivity is present.

Prior to working near radioactive or radioactive-contaminated materials, machine shop personnel, and in particular the shop foreman, should become familiar with the 00-110 technical order series. This series provides useful information about safety precautions, decontamination procedures, and radioactive waste disposal.

Exercises (018):

1. What are probably the most important pieces of protective equipment that you could take to the flight line with you? Why?

2. What particular hazard is prevalent in cold weather areas? In hot weather areas?

3. What three hazards other than noise must you protect against when working around an operating jet engine?

4. Many accidents occur around operating propellers. Why?

5. Engine noise can cause health problems, other than merely damaged hearing. Explain.

6. Why must you be able to recognize radiation warning signs?

7. What technical order series provides information about radiation safety precautions?

3-3. Ground Accident Reporting.

From time to time, accidents are going to happen. When an accident does occur, what should you do? Whom should you tell? Who is responsible for reporting it? In this section, we shall briefly discuss the purpose of reporting ground accidents and some basic guidelines for reporting them.

019. State the purpose and indicate the responsibility and procedures for reporting ground accidents.

Purpose of Accident Reporting. To better understand our discussion on ground accident reporting, we should first determine what a "ground accident" really is. According to AFR 127-4, *Investigating and Reporting US Air Force Mishaps*, a ground accident is a mishap that occurs on ground or water, on or off an Air Force installation, that involves Air Force military personnel, Air Force civilian personnel, or Air Force property. This term, however, does not include those accidents that are classified as aircraft, explosives, missile, or nuclear accidents. (Although our discussion is concerned with ground accidents, you should report *all* accidents that you are part of, or witness to, no matter what classification they fall into.)

The primary purpose of an accident report is to get all the facts pertaining to an accident so that the cause of the accident can be determined. Other purposes of the report are to determine losses and to indicate preventive actions. In other words, it is necessary to find out what caused the accident, how much it cost, and what can be done to prevent its repetition. Accident reports should be used as management tools by supervisors. When properly analyzed, the reports may indicate such factors as state of training, attitudes of personnel, violations of safety regulations, and/or specific unsafe features of a particular operation.

Reporting Procedures. As we stated previously, you should report all accidents. If you are involved in or are witness to an accident, it is your responsibility to report it to your immediate supervisor. If the accident does not involve a disabling injury or property damage in excess of 100 dollars, the supervisor may not be required to make an official report; however, you should allow your supervisor to make that decision, based on local directives.

You must be specific and, to the best of your knowledge, report all the facts pertaining to the accident. The supervisor, who has the primary responsibility for reporting ground accidents to the ground safety office, will need all of the facts to make a proper analysis of the accident. It is essential that the actual cause of the accident be determined.

You must be specific and, to the best of your knowledge, report all the facts pertaining to the accident. The supervisor, who has the primary responsibility for reporting ground accidents to the ground safety office, will need all of the facts to make a proper analysis of the accident. It is essential that the actual cause of the accident be determined. In most cases, the cause is found to be an unsafe act or condition. Once the cause is determined, the proper corrective action can be taken. This will prevent a repetition of similar accidents.

Exercises (019):

1. Who has the primary responsibility for reporting accidents to the ground safety office?

2. What is the main purpose of an accident report?

3. What are the most common causes of accidents?

4. Why must the supervisor be given all the facts pertaining to an accident?

CHAPTER 4

Shop Drawings

CAN YOU IMAGINE the confusion that would be caused if aeronautical engineers were forced to use only word-of-mouth to transmit their thoughts to the machinist? Needless to say, many parts would be wasted before one was produced that met the engineer's plans. Fortunately, the art of putting design plans on paper is representative picture form has been developed over the years. This art, known as mechancial drawing, is used to produce the thousands of drawings and diagrams needed o guide the machinist as the engineer's plans are turned into actual parts. This chapter will help you understand the various types of mechanical drawings and the standard drawing or drafting practices. You will also learn some techniques for sketching your own shop drawings. You will need this information if you are to do an effective job of turning a mechanical drawing into a newly manufactured or repaired part. You will also use this information when you work directly on aircraft and support equipment. In other words, drawings of one kind or another will be a part of your everyday life as a machinist, so a knowledge of how to read and interpret them is imperative.

4-1. Maintenance Drawings

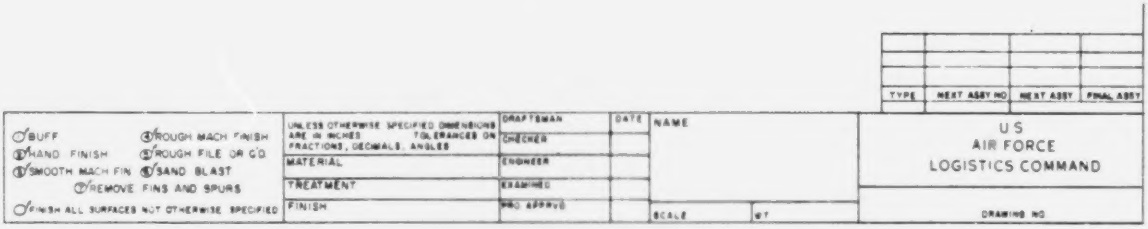
You will be using many different types of drawings as machining guides and you should be familiar with each of them. In this section, we shall discuss blueprints in general and then some of the various technical order drawings.

020. Explain the use and meaning of various types of maintenance drawings.

Blueprints. As you probably know, a blueprint is simply a copy of a mechanical drawing. The term originated because most prints were reproduced as white lines on a blue background. Currently, prints are reproduced in several different colors, depending on the type of reproduction machine and paper used. but they are still generally referred to as blueprints.

The Air Force stores and catalogs enormous numbers of drawings for all of the equipment under its control. It would be impractical to store full-size prints at each base or unit, so the drawings have been reduced to miniature microfilm prints and attached to IBM cards. These cards are then filed by part number for easy reference. If you were repairing a certain aircraft part and needed more information on the tolerances allowed, you could look in the card file and pick out the card with the correct part number on top. This card could then be placed in the microfilm viewer, and you could read the required information on a TV-type screen. Also, the machine could produce full-size reproductions of the prints for you if you need them. These microfilm files and machines are normally located in the reparable processing center (RPC), which is operated by the production control unit under the chief of maintenance. Personnel in this unit are responsible for keeping the files undated and for maintaining the microfilm machine. Be sure to check with an attendant in the section before operating the equipment; it is expensive and easily broken.

Anytime that you must work from a blueprint, the first thing to do is to look at the *title block*. A typical title block is shown if figure 4-1. Exact layout of title blocks will differ slightly, depending on the origin and the type of drawing. Here you will find such information as the material needed to make a part, the heat treatment required, the tolerances specified, the scale of the drawing, notes on the finish required, and complete print identification (name of the part or assembly, the engineer or draftsman, the organization responsible, and the date that the drawing was completed). Also, on certain types of drawings or prints, you will find a *bill of materials*. This is a list of all the parts used in a particular assembly, such as a die assembly. This type of list is important when a person is ordering the


BUFF
① HAND FINISH
② SMOOTH MACH FIN
③ ROUGH MACH FINISH
④ ROUGH FILE OR G'D
⑤ SAND BLAST
⑦ REMOVE FINS AND SPURS
FINISH ALL SURFACES NOT OTHERWISE SPECIFIED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS, DECIMALS, ANGLES
MATERIAL
TREATMENT
FINISH
DRAFTSMAN
CHECKER
ENGINEER
EXAMINED
PRO APPRVD
DATE
NAME
SCALE
WT
TYPE
NEXT ASSY NO
NEXT ASSY
FINAL ASSY
U S
AIR FORCE
LOGISTICS COMMAND
DRAWING NO

53-1442

Figure 4-1. Blueprint title block.

standardized parts involved in the production of that particular unit.

Technical Order Maintenance Drawings. Many drawings are contained within the various technical orders that you will be using. They are essentially the same as blueprints or mechanical drawings except that they don't have title blocks. Footnotes are used to identify specific information, such as the scale of the drawing, the finish and heat-treatment required, etc. We shall briefly discuss three types of drawings commonly found in technical orders (TOs): the working drawing, the assembly drawing, and the exploded drawing. Although our discussion will be concerned with TOs, the types of drawings are common to blueprints or mechanical drawings as well.

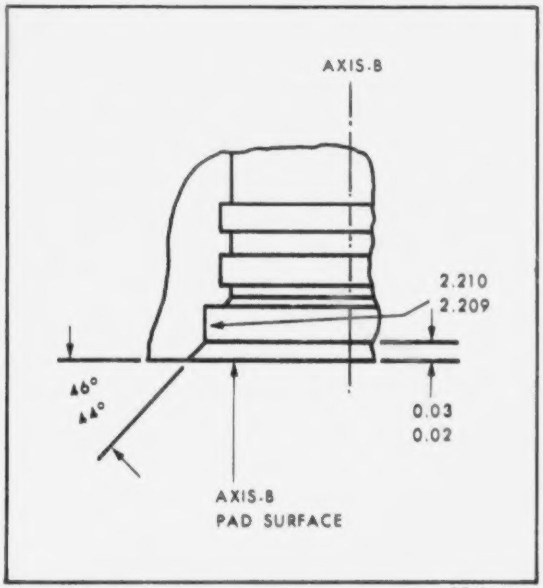
Working drawing. A working drawing (sometimes referred to as a production drawing) conveys the information necessary for the production of individual parts. One drawing may depict more than one part, but when two or more parts are involved, they will each be dimensioned and described sufficiently to provide all the production information required.

As a machinist, you will be using TO working drawings to guide you in the manufacture of such items as special tools, jigs and fixtures, certain replacement parts, and special inserts and bushings. Also, some TO working drawings depict only a portion of a larger part, as in figure 4-2. Here, inly a particular operation, making a chamfer, is required to modify an existing part.

Assembly drawing. There are several types of assembly drawings. As the name implies, they contain a partial or complete assembly instead of one or two specific parts. Also, they normally do not include dimensions, except possibly the overall dimensions of the assembled unit, the distances between centers, or certain other dimensions that do not apply to any particular part.

One type of assembly drawing, the *unit assembly drawing,* shows a completely assembled unit in such a way that all the parts can be seen. This "increased visibility" is usually effected by *sectioning* the unit i.e., providing a cutaway drawing that reveals internal parts and shapes). This type of drawing shows the proper positioning of the parts within the assembled unit. A jet engine bleed valve might be depicted in this manner in a TO.

Another type of assembly drawing is the maintenance assembly drawing, such as the one in figure 4-3. These drawings show units or assemblies in the process of being assembled. They are used in TOs to give a person directions for installing or removing various parts of a particular unit. Such things as torque valves and particular adjustment settings might be specified on this type of drawing. Before drilling out a broken stud, you might refer to this type of drawing to determine whether there are any hidden parts attached to it or whether the threaded area extends into an oil chamber.


AXIS-B
2.210
2.209
46°
44°
0.03
0.02
AXIS-B
PAD SURFACE

53-1440

Figure 4-2. Technical order working drawing.

BEST COPY AVAILABLE

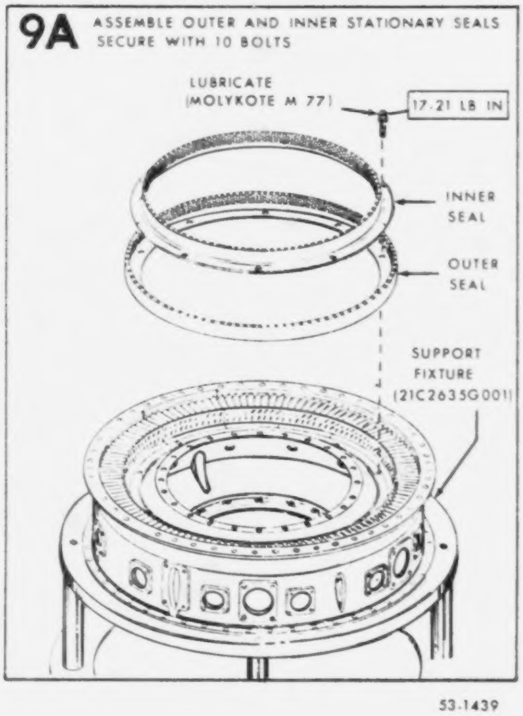


Figure 4-3. Technical order maintenance assembly drawing.

Exploded drawing. An exploded drawing is actually another form of an assembly drawing. It is used to show the proper relationship of the parts of a unit, not as a final assembled unit but as if the unit were "exploded," or taken apart without the parts losing their relative positions, as in figure 4-4. In TOs, this type of drawing is referred to as a parts breakdown. End items such as aircraft and AGE units have one or more TO volumes each that contain parts breakdown drawings of the various assemblies within the particular items. In a TO, each exploded drawing is accompanied by a parts reference list. Each numbered part on the drawing is entered on the list, which gives the name of the part, the number of times that the part is used in the assembly, the part number, and other information as necessary. These drawings are useful for such things as obtaining part numbers for various parts, identifying the correct part to use, and determining the proper installation sequence for the various parts.

Exercises (020):

1. What does the term "blueprint" mean?

2. How are copies of mechanical drawings stored in the Air Force?

3. List at least five items that you could expect to find in the title block of a blueprint.

4. What information would be given in the bill of materials on a print or drawing?

5. List the types of drawings commonly found in Air Force TOs.

6. What kind of drawing would contain the information that you would need to machine a drill jig to the correct dimensions?

7. Briefly describe a unit assembly drawing.

8. What type of drawing is called a parts breakdown? How is it used in TOs?

4-2. Drafting Practices.

To be able to correctly interpret blueprints and drawings, it is necessary that you understand the different practices employed in producing or drafting them. This section will give you a brief review of some things that you may remember from your 3-level studies and also some new information that you may not be aware of. We shall discuss orthographic projection, the various kinds of lines used, the purpose of the various views used in drafting, dimensioning practices, and the use of the metric system in drafting.

021. Describe orthographic projection.

Orthographic Projection. In orthographic projection, an object is shown on paper in some combination of front, top and side views.

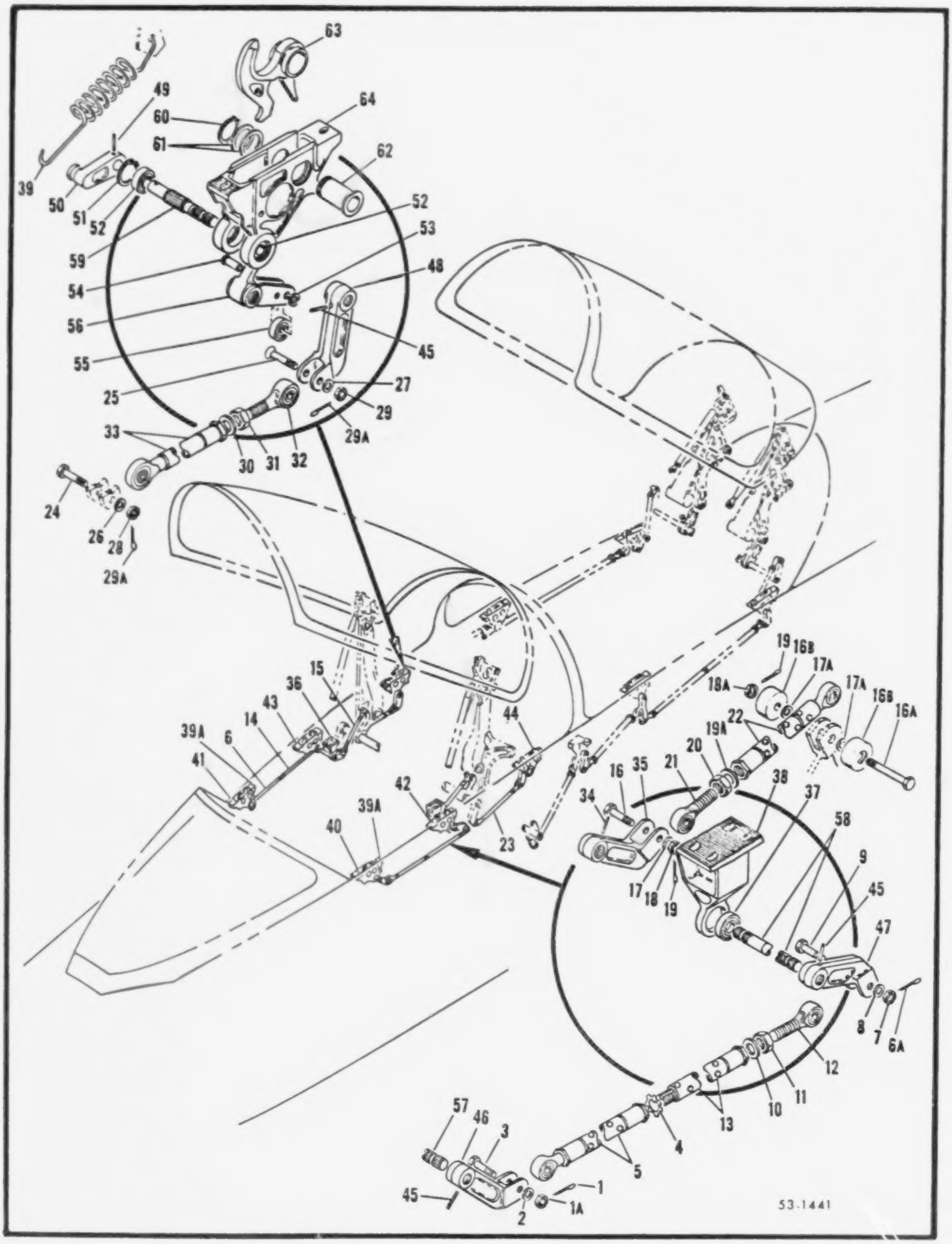

63
49
64
60
61
62
39
50
51
52
52
53
59
48
54
56
45
55
25
27
29
29A
33
30
31
32
24
26
28
29A
15
36
43
14
39A
6
41
44
42
39A
40
23
19
16B
17A
18A
17A
16B
16A
22
19A
20
21
16
35
38
34
37
58
17
18
19
9
45
47
8
7
6A
12
11
10
13
4
5
57
46
3
45
2
1A
1
53-1441

Figure 4-4. Technical order exploded drawing.

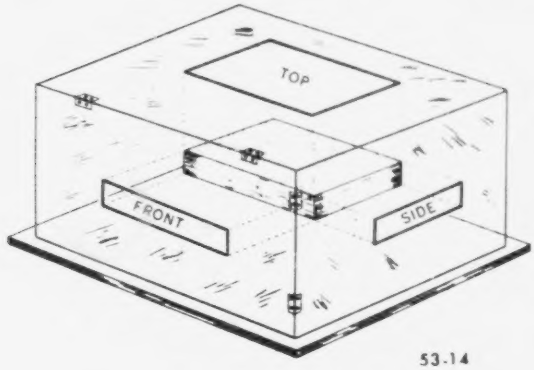


Figure 4-5. Projected view of an object.

Figure 4-5 is an example of how the different views of an object are visualized. Orthographic projection does not show an object in perspective. In other words, it isn't shown the way our eyes would see it (those things nearest us appear larger than things farther away). Instead, orthographic projection presents "true views" of an object so that all the lines of the object appear in their true length somewhere in the drawing. If the top and side of the transparent box in figure 4-5 were opened so that they would be in the same plane as the front, you would see the length, width, and height in true dimension.

Notice that the block pictured in figure 4-5 would really only require two views to show all of its features. But, if there were several holes drilled into one end and a step extending part of the way across the front, then all three views would be much easier to interpret. Some objects require only one view to convey all of the features: a sphere, for instance, or a plain round rod if the dimensions were given as length and diameter. In most cases though, even a plain round rod will have two views just for the sake of clarity.

If the object has a complicated or irregular shape, more than three views may be needed. The number of views needed will depend upon how much detail the machinist needs. Detail in any one view should be kept to a minimum to avoid cluttering up the view and making it difficult to read.

Views are drawn in their correct relationship with one another. The top view is placed above the front view, and the right-side view is placed to the right of the front view. A view placed out of position is confusing. A multiview drawing should not contain more views than necessary to describe the object fully. In presenting views, draftsmen usually observe the following principles:

- Views showing essential contours are selected.
- Views with the least amount of invisible lines are preferred.
- Right-side views are preferred to left-side views, unless the left-side view conveys more information.
- The top view is preferred to the bottom view, unless the bottom view conveys more information.
- In presenting views, the available space should be considered.
- The principal view is the one that shows the characteristic contour of the object. It is good practice to use this view as the front view on a drawing, regardless of the natural front of the object.

Exercises (021):

1. How does orthorgraphic projection present an object?

2. How many views of an object are required in orthorgraphic pictures?

3. How is the view that our eyes see of an object different from the view depicted in orthographic projection?

4. The principal view should be used as the ________ view wherever possible.

022. Identify various types of lines and their uses in drafting.

Types of Lines and Uses. The types of lines used to draw the views of an object help you to interpret a drawing. These lines are made in definite, standard ways. The relative thickness of the line (fine, medium, thick) and the composition (broken, solid, dashes, etc.), as shown in figure 4-6, signify various meanings that you must understand if you are to correctly read a drawing. The composition and use of various lines are as follows:

a. Centerlines consist of long and short dashes, alternately and evenly spaced with a long dash at each end and short dashes at

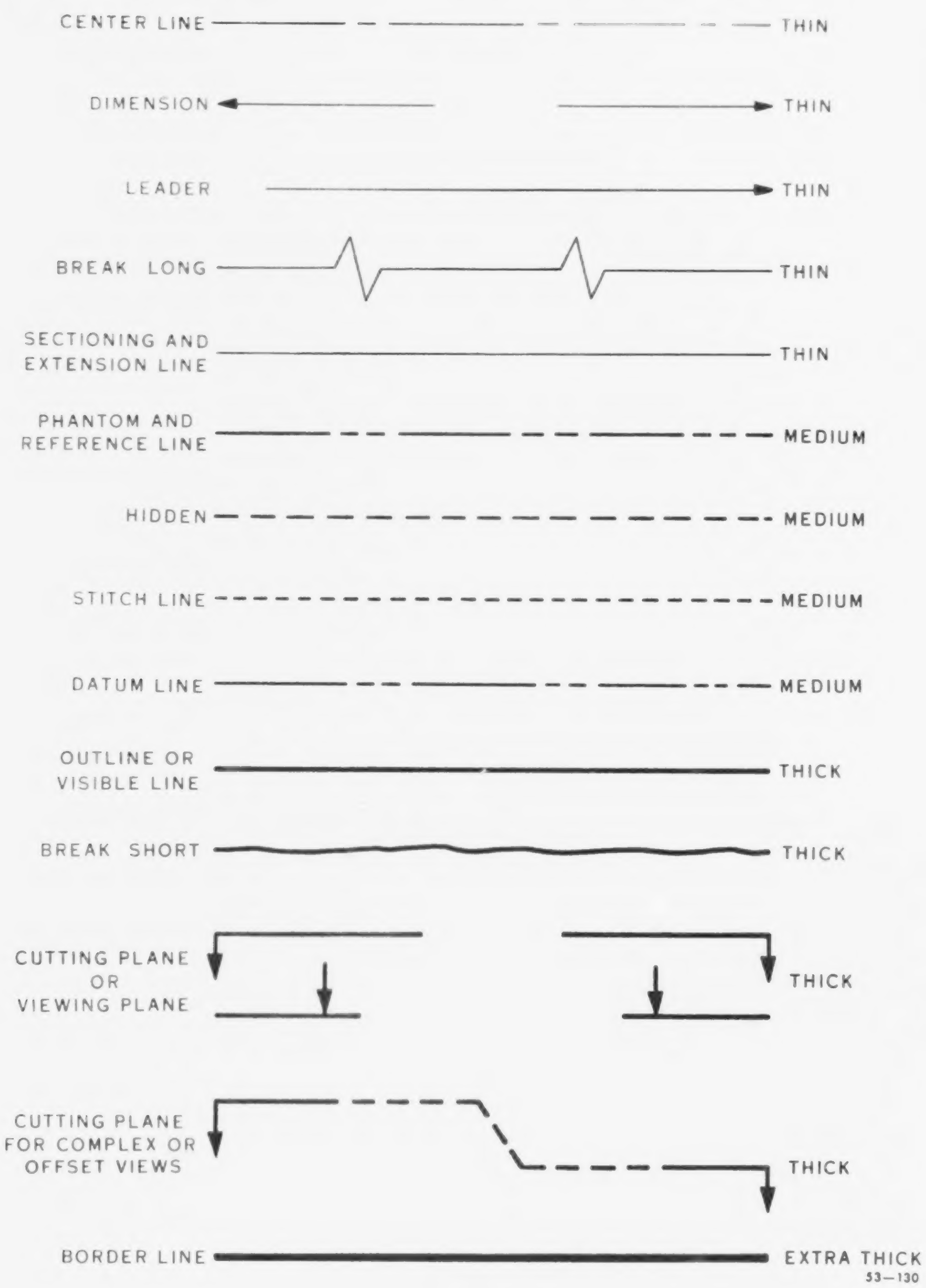

CENTER LINE
THIN
DIMENSION
THIN
LEADER
THIN
BREAK LONG
THIN
SECTIONING AND EXTENSION LINE
THIN
PHANTOM AND REFERENCE LINE
MEDIUM
HIDDEN
MEDIUM
STITCH LINE
MEDIUM
DATUM LINE
MEDIUM
OUTLINE OR VISIBLE LINE
THICK
BREAK SHORT
THICK
CUTTING PLANE OR VIEWING PLANE
THICK
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS
THICK
BORDER LINE
EXTRA THICK
53—130

Figure 4-6. Line thickness, composition, and meaning.

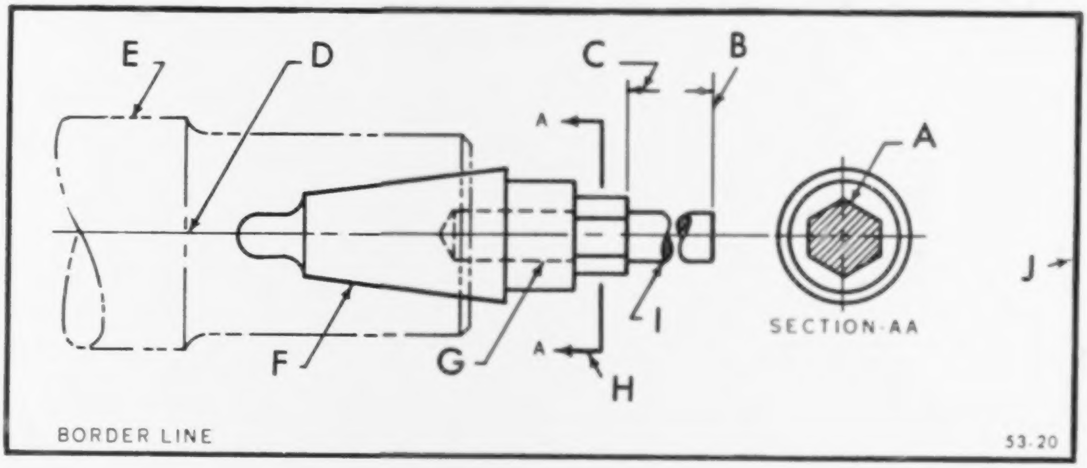


Figure 4-7. Use of various lines.

points of intersection of centerlines. Very short centerlines, as in figure 4-7, may be broken if there is no confusion with other lines. Centerlines are also used to indicate the travel of a center.

b. *Dimension* lines terminate in arrowheads at each end, as shown in figure 4-6. They are broken where the dimension is inserted.

c. *Leader* lines indicate a part or area to which a number, note, or other reference applies. Usually the leader lines terminate in an arrowhead, as in figure 4-6.

d. *Break* lines are used when an object is uniform in shape, such as a pipe or shaft, and the length prevents its being shown completely on a drawing. A portion is removed from its midsection, as shown in figure 4-7, to enable both ends of the object to be seen. Short breaks are indicated by solid, freehand lines, as in figures 4-6 or 4-7. For long breaks, full, ruled lines with freehand zigzags are used. as in figure 4-6. Shafts, rods, and tubes have the ends of the break drawn as indicated in figure 4-7.

e. *Phantom* lines are used to indicate alternate positions of parts of an object, repeated detail or the locations of absent parts, as in figure 4-7. They are made by alternating one long and two evenly spaced short dashes with a long dash at each end.

f. *Sectioning* lines are used to indicate the exposed surfaces of an object in a sectional view, as in figure 4-7. They are usually full, thin lines but may vary with the type of material shown. Figure 4-8 shows some of the standard ways of using sectioning lines to represent specific types of materials.

g. *Extension* lines are used to indicate the extent of a dimension, as in figure 4-7. They do not touch the outline of the object but terminate within one-sixteenth of an inch from it.

h. *Hidden* lines consist of short, evenly spaced dashes to show hidden features of an object, as shown in figure 4-7. They always begin with a dash in contact with the line from which they start, except when a dash would form a continuation of a full line.

i. *Stitch* lines, shown in figure 4-6, indicate the stitching or sewing lines on an article. They consist of a series of very short, evenly spaced dashes, about one-half the length of the dashes used for hidden lines.

j. *Outline* or *visible* lines are solid, thick lines used to represent all visible lines on the object, as in figure 4-7.

k. *Datum* lines, shown in figure 4-6, are made by alternating one long and two short evenly spaced dashes of medium thickness. They are used to show surfaces not present in the drawing from which positions are located.

l. *Cutting plane* lines are used to indicate a plane in which a sectional view is taken as shown in figure 4-7.

m. *Viewing plane* lines, as shown in figure 4-6, are used to indicate the plane from which a surface is viewed.

n. *Border* lines are extra-heavy lines used to frame or inclose the entire drawing and to give the drawing a "finished" appearance, as shown in figure 4-7.

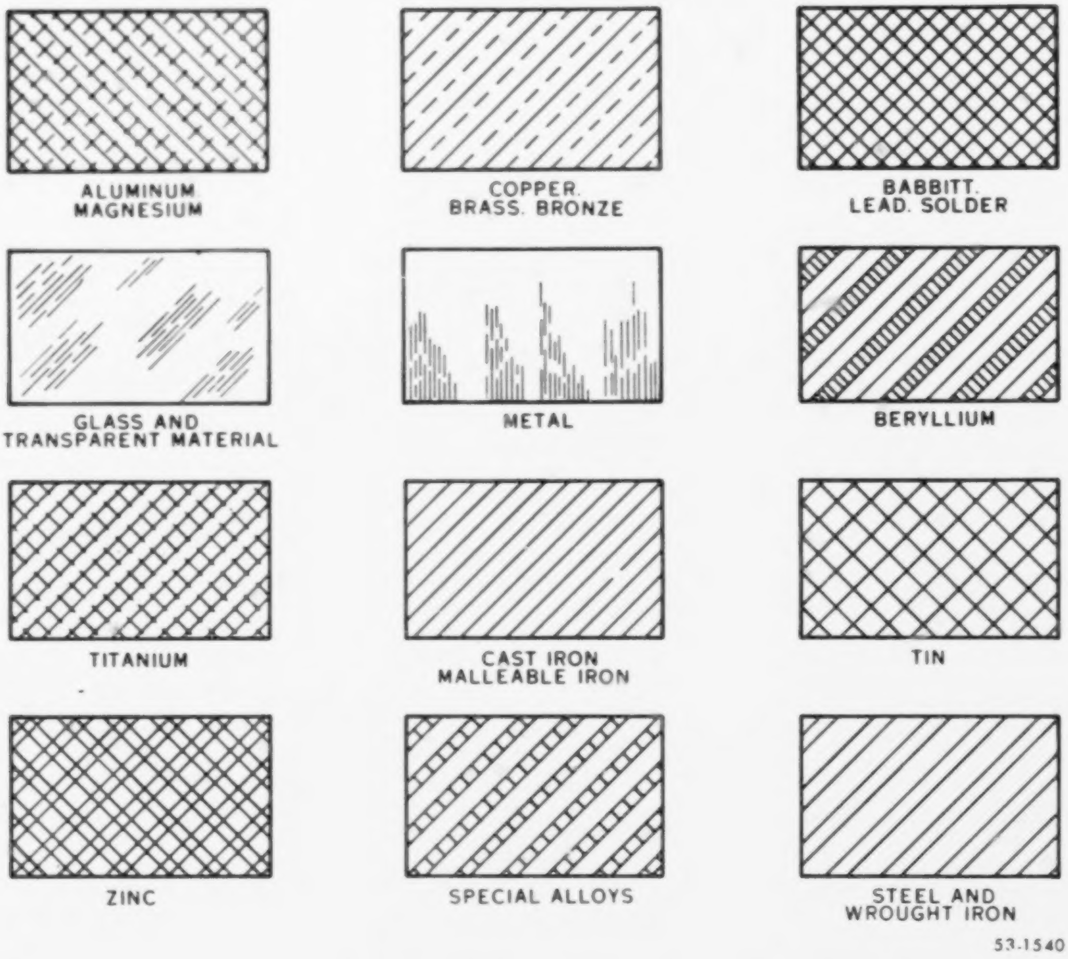

ALUMINUM MAGNESIUM
COPPER. BRASS. BRONZE
BABBITT. LEAD. SOLDER
GLASS AND TRANSPARENT MATERIAL
METAL
BERYLLIUM
TITANIUM
CAST IRON MALLEABLE IRON
TIN
ZINC
SPECIAL ALLOYS
STEEL AND WROUGHT IRON
53-1540

Figure 4-8. Material symbols.

Exercises(022):
Enter in the spaces provided the correct names of the lines described in the following statements.

_______________ 1. Single, thin line consisting of evenly spaced long and short dashes.
_______________ 2. Thin lines that indicate the object of note or number.
_______________ 3. Medium line consisting of alternating one long and two short, evenly spaced dashes.
_______________ 4. Extra-heavy lines.
_______________ 5. Thick freehand line.

023. Describe auxiliary views and the various sectional views used in blueprints and drawings.

Auxiliary Views. Some objects contain slanted surfaces that do not appear in their true outlines in any combination of front, side, top, or bottom views. Many times these surfaces must be shown in their true appearance in order to clarify the shape or particular details. This is done with auxiliary views. They are views projected off a profile of the slanted surface in the same way that a side view is projected off a front view. They normally present only the particular surface in question instead of presenting the entire object. Since the reason for the auiliary view in the first place was for clarification, it would make no sense to clutter the view with the rest of the object, which would not appear in true proportions anyway.

Sectional Views. When it becomes necessary to more clearly illustrate internal portions of an object, a *sectional view* is used. A sectional view is like looking at an object after it has

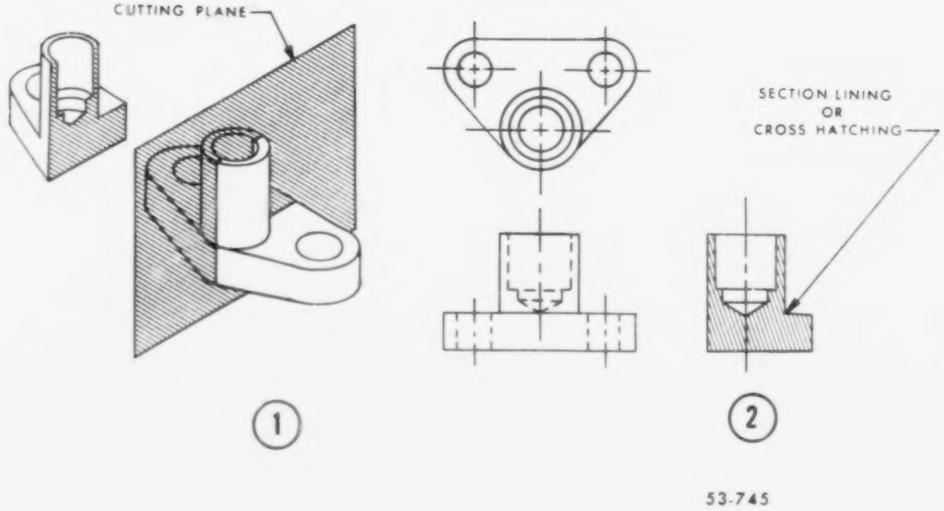


Figure 4-9. Sectional view.

been partially or completely sawed apart in a prescribed manner. The path of the saw is considered the cutting plane; that is, the plane on which the cut was made, as illustrated in figure 4-9, part 1. In this type of view, formerly invisible or hidden lines become visible lines. Surfaces that were "sawed through" are crosshatched to make the newly visible portions stand out, as shown in figure 4-9, part 2. This crosshatching normally symbolizes the type of material used (as was shown in fig. 4-8) and consists of various kinds of evenly spaced lines drawn at 45° angles across the surface. The exact path of the cutting plane can vary greatly and is shown by the use of a cutting plane line; the arrows at the ends of the line show the direction of the view, as was shown in figure 4-7.

There are many ways of presenting sectional views. We shall briefly discuss several of them.

Full section. Full sectional views are obtained by passing the cutting plane across the entire object, exposing the entire inner surface, as shown in figure 4-10.

Half section. Half sectional views are obtained by passing two cutting planes at right angles to each other along the centerlines or symmetrical axes, exposing one half of the inner surface, as in figure 4-11. The unexposed portion of the sectional view usually does not have hidden object lines, but it may have them if the internal area is very complex.

Partial section. Partial sectional views are used when it is desired to show only a portion of the object in cross section. The broken-out area is bounded at the break with short break (freehand) lines, as shown in figure 4-12.

Offset section. In some cases, it is necessary to draw a series of two or more cutting planes through an object in different directions. When the cutting plane consists of two or more intersecting planes, except for the 90° half section, the view is called on offset section. The lines of intersection where the cutting planes intersect are not shown on the sectional view. The direction or position of each cutting

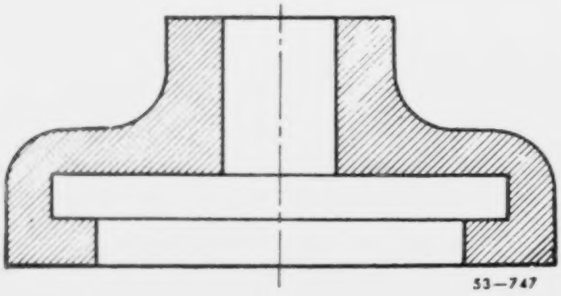


Figure 4-10. Full section.

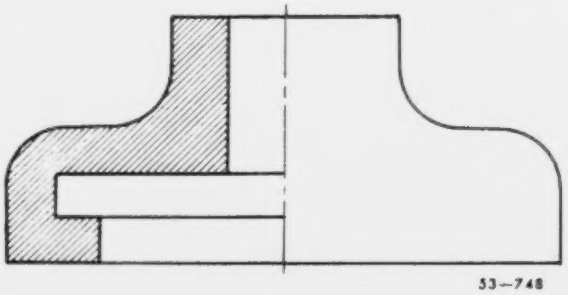


Figure 4-11. Half section.

plane is shown by the cutting plane line, as shown in figure 4-13.

Aligned section. In some cases, the true projection may be misleading if parts, ribs, spokes, and drilled holes are drawn in their actual locations. In such instances, these portions may be rotated into, or out of, the cutting plane as in figure 4-14. The resulting section, called an aligned section, is not a true projection, but it is easier to read and gives a better description of the object.

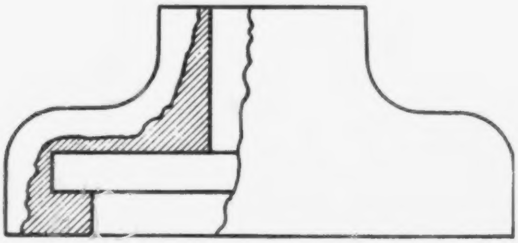


Figure 4-12. Partial section.

Revolved and removed sections. A revolved section is made directly on one of the principal outline views. The cutting plane is passed perpendicular to the centerline or axis of the part to be sectioned, and the resulting section is revolved 90° into the plane of the paper, as shown in figure 4-15. Revolved sections are used primarily for shape description and are sometimes dimensioned. When this type of view is taken out of the principal view, it is called a removed section. Such views are connected to the view from which they were removed by a centerline, as in figure 4-16. Placing the sectioned view away from the object allows it to be enlarged for clarity if necessary. Cutting plane lines or section titles are not used with either revolved or removed sections.

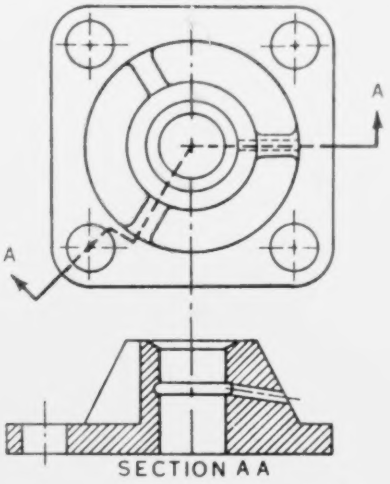


Figure 4-13. Offset section.

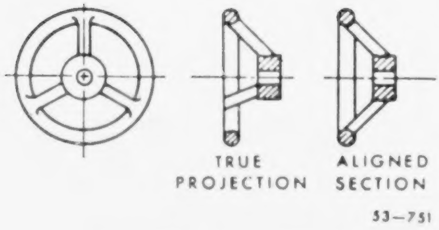


Figure 4-14. Aligned section.

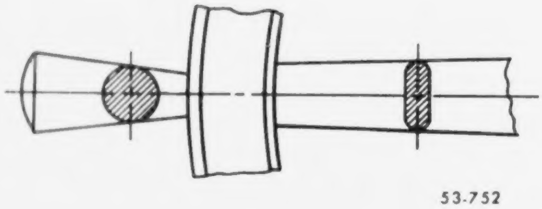


Figure 4-15. Revolved section.

Thin section. Sections such as sheet metal, structural shapes, packing gaskets, etc, may be shown solid in the sectional view (as in fig. 4-17), with a very narrow space left between thicknesses of such parts.

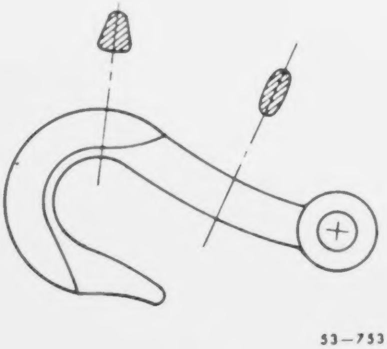


Figure 4-16. Removed section.

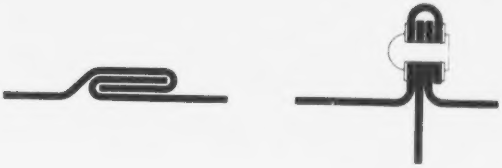


Figure 4-17. Sheet metal sections.

Interpreting Sectional Views. Some other points to remember when you are interpreting various sectional views areas follows:

a. When a cutting plane passes through a rib, web, or similar parallel portion of an object, the crosshatching is omitted from those parts (unless some particular detail must be shown). The cutting plane is thought of as passing just in front of the rib or web, as in figure. 4-18.

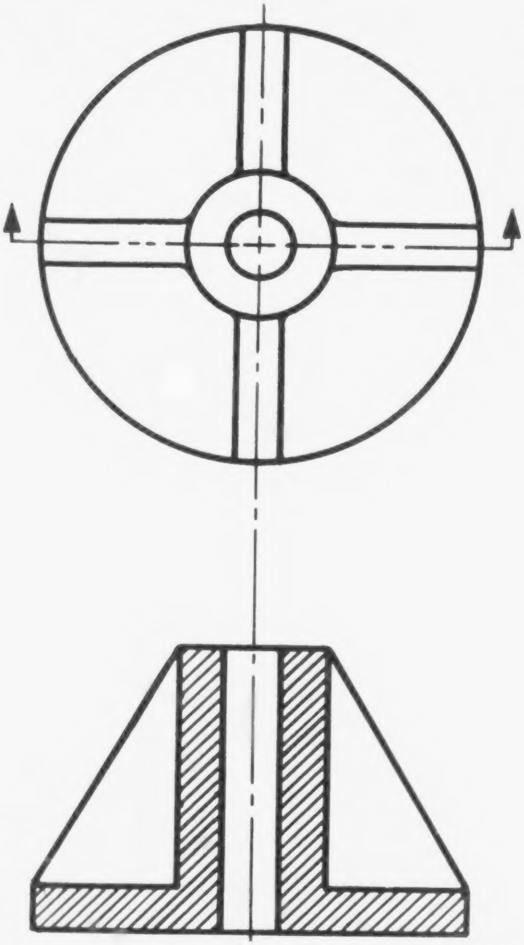


Figure 4-18. Ribs in section.

b. When adjacent parts are shown in section, the crosshatches are shown in the opposite direction, as in figure 4-19. However, when different places on the same part are sectioned, all of the crosshatching is the same.

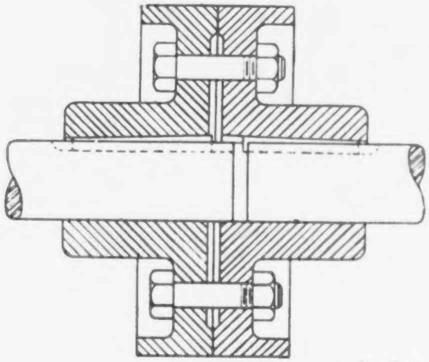


Figure 4-19. Two adjacent parts in section.

c. When three adjacent parts are in section, two of them have 45° crosshatching in opposite directions, and the third part is crosshatched at a 30° or 60° angle, as in figure 4-20.

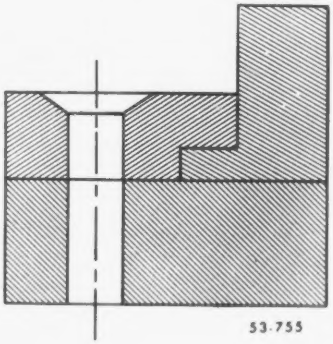


Figure 4-20. Three adjacent parts in section.

Exercises (023):

1. What is the main purpose of an auxiliary view?

2. When a cutting plane passes through an object, how are the resulting new surfaces depicted?

3. What is the name given to a sectional view that is bounded by short break lines?

4. What sectional view would result from three different intersecting cutting planes passing through an object to form one view?

5. Are parts such as ribs or spokes ever shown purposely out of their true position in sectional views? Under what circumstances?

6. How is the crosshatching affected when three adjacent parts are shown in section?

024. Explain various dimensioning practices.

Dimensioning Practices. If it were not for dimensions, a drawing or blueprint could do little more than give you an idea of the shape of an object. On the other hand, when dimensions are used, the print can be made to convey all the details about the object. However, you must be able to read and interpret these dimensions if they are to serve their purpose completely.

As you may recall from your studies for the 3 skill level, dimensions fall into three general groups: detail, position, and overall. A detail dimension shows one length or dimension necessary to express the size of the structure. A position dimension locates the centers of circles or radii necessary to fabricate structures to exact dimensions. An overall dimension is a total dimension, giving the entire length, height, and width of an object or structure. It is generally a summation of smaller dimensions and is placed on the outside of detail and position dimensions.

An example of how each of these groups is used is given in figure 4-21. Most dimensions are self-explanatory as far as interpreting them is concerned, so we shall limit our

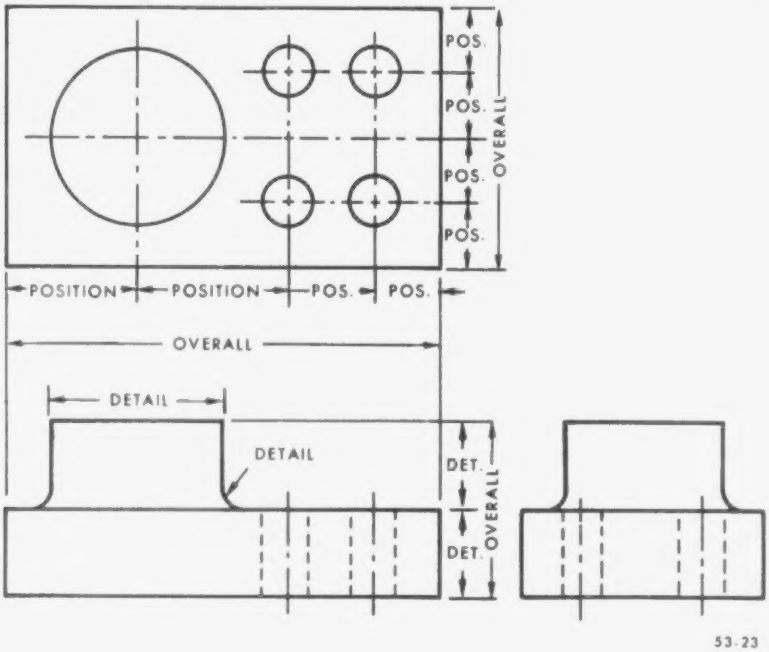


Figure 4-21. Types of dimensions.

discussion to some terms and practices in which the meaning is not so readily apparent.

Tolerance and Allowance. Mass production has brought about the need for interchangeable parts. Mating parts may be manufactured and assembled in entirely different factories. To make parts that can be interchanged, sizes must be specified in such a way that machine operators in widely separated shops can produce parts that are interchangeable. Attaining interchangeability would be a simple task if it were possible to manufacture parts exactly to the dimensions intended in the design. It is the problem of the designer to specify the allowable amount of error that can exist and still permit the parts to function satisfactorily.

"Tolerance" is the amount of variation permitted in the dimension or surface of machine parts. Tolerances are stated in several ways. They may be stated as limits. For example, a piece is to be made 1.950 inches long with a maximum dimension +.002 inch larger than 1.950 inches and with a minimum dimension -.003 inch less than 1.950 inches. The extreme dimensions are indicated by $1.950\ ^{+.002}_{-.003}$ The maximum dimension is 1.952 inches, and the minimum dimension is 1.947 inches.

"Unilateral tolerance" is related to the basic size or dimension in one direction only. For example, if the size of a shaft is 1.000 inch and the tolerance is expressed as 1.00 + .001 and —.000, this is a unilateral tolerance. If the tolerance is expressed as partly plus and partly minus, it is a "bilateral tolerance." Then the size of the shaft is stated as 1.00 inch $^{+.001.}_{-.001}$ because the total tolerance is given in two directions. When you wish to express unilateral tolerance, use one of the three following methods:

- Specify limiting dimensions:
  Hole size: 3.250, 3.252
  Shaft size: 3.249, 2.247
- Specify one limiting size:
  Hole size: 3.250 + .002, —.000
  Shaft size: 3.249 + .000, —.002
- Specify nominal size for both, showing both allowance and tolerance.
  Hole size: 3¼ + .002, —.000
  shaft Size: 3¼ —.001, —.003

Bilateral tolerance should be specified with a plus and minus tolerance, usually of an equal amount.

"Allowance" is the intentional difference in the dimensions of mating parts, and may be positive or negative. The allownace is positive if there is a clearance between the external part and the internal part. The allowance is negative if the internal part is larger than the external part.

Threads. Threaded holes and shafts may be illustrated as they actually appear, as shown in figure 4-22, part A; by the conventional method, part B; or by the simplified method, part C. In any case, the diameter of the thread, the number of threads per inch, the thread series, and the class of fit are given, as illustrated in figure 4-22 to the right of part C. The abbreviation LH is used following the thread designation for left-hand threads only; for example, 1/2-13-NC-3-LH.

Surface Finish Symbols. On many drawings and prints, it is important to specify just how smooth or rough a particular surface can or must be. Some parts must have a highly polished surface while others are perfectly serviceable in a rough machined state. Therefore, during the dimensioning process, surface

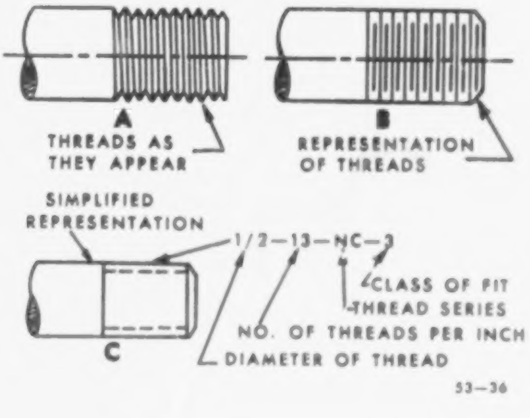


Figure 4-22. Dimensioning threads.

condition requirements are noted by the use of various "finish symbols," shown in figure 4-23.

Finish symbols are marks made on the visible or invisible lines that represent the edges of the surface to be machined. Where it is not necessary to control the roughness of the surface, the symbol can be the italic symbol as shown in figure 4-23 (1) or by a 60° "V" drawn with its point touching the line representing the surface to be finished, as shown in figure 4-23 (3).

Letter symbols can be inserted in the "V" to specify the type of finishing operation. Figure 4-23 (4) shows the letter "G" inserted in the "V", meaning that the surface should be ground. "R" and "S" are sometimes used to specify "rough machining" and "smooth machining" respectively. A "G" by itself on the surface line, as in figure 4-23 (2), also indicates that the surface should be ground.

The American Standard Association, in order to develop a system of indicating the desired finish more accurately, has adopted a finish symbol that looks like a check mark with a horizontal extension bar as shown in figure 4-23 (5) and (6). A numerical note can be inserted within the checkmark to indicate the surface roughness required. For instance, the finish symbol shown in (5) specifies a surface roughness height of 50 microinches (millionths of an inch). Roughness is considered to be irregularities spaced less than one thirty-second of an inch apart. A numerical note placed above the horizontal line, as in (6), indicates the waviness height and is normally expressed in thousands of an inch. Waviness is considered to be those surface irruglarities that are spaced more than one thirty-second of an inch apart.

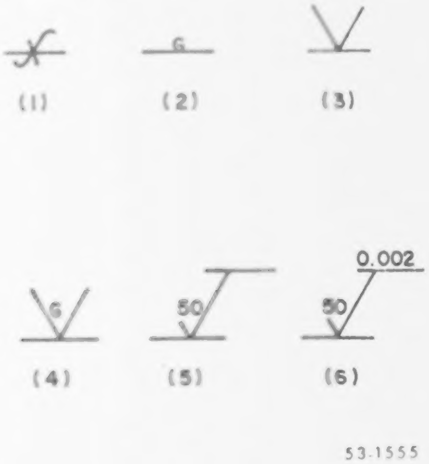


Figure 4-23. Surface finish symbols.

Exercises (024):

1. What do position dimensions show?

2. What term is applied to the amount of variation allowed in the dimension of a part?

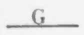
3. 2.312 $\substack{+\ .002 \\ -.002}$ is an example of tolerance.

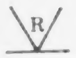
4. 3.312 + .000, -.002 is an example of tolerance.

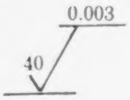
5. Define "allowance" as used in dimensioning.

6. What information is given about a thread when it is dimensioned?

7. What do the following surface conditions, dimensions, or symbols indicate?

a.


b.


c.


025. Indicate procedures for calculating and interpreting metric measurements on drawings and blueprints, and convert millimeters to inches and inches to millimeters.

As you probably know, the United States is gradually phasing into the metric system of measurement and away from the use of inches, feet, etc. Naturally, the Air Force is converting also. More and more of the work done in Air Force machine shops will require a knowledge of the metric system how to convert dimensions to and from the metric system, and how to interpret metric drawings and prints.

Metric Conversion. The two units of metric measure that you will use most as a machinist are the meter and the millimeter. The meter is equal to 1000 millimeters. A meter converts to inches, feet, and yards in the following manner:

39.37 inches
1 meter = 3.28083 feet
1.0936 yards

One millimeter is equal to 0.03937 inch, which is almost 1/25 of an inch. Conversely, 1 inch is equal to 25.4 millimeters.

Perhaps the best way to compute the exact conversion of a particular number to or from the metric system is to look at the metric conversion tables given in publications such as the *Machinery's Handbook*. However, in the absence of those tables, you could use the following methods.

Suppose the length of a line on a drawing was given as 10.32 millimeters and you need to convert it to inches. First, you can make a good approximation (remember that 1 millimeter is close to 1/25 inch by multiplying the number of millimeters (rounded off to the nearest whole number) by 1/25:

10 x 1/25 = 10/25 = 2/5 or between 25/64 and 13/32 inch.

To get the exact conversion, multiply the number of millimeters by 0.3937:

10.32 x 0.03937 = 0.4062984 inch or 13/32 inch (0.40625)

If the line on the print was given as 2.250 inches and you need to know how many millimeters that is equal to, you could approximate quickly by allowing 25 millimeters for each inch.
For example:

2.250 = 2 1/4 = 2 1/4 x 25 = 56 1/4 millimeters or approximately 56 millimeters

The exact number of millimeters can be obtained by multiplying the number of inches by 25.4:

2.250 x 25.4 = 57.1500 millimeters

Metric Dimensioning. When metric dimensions are given on drawings or prints, they are nearly always given in millimeters (mm), even on prints of such large objects as locomotives. The practice of utilizing only one unit of measure has been adopted in order to reduce the tendency to misplace decimal points or to misread dimensions.

In many cases, dimensions given in millimeters can be specified without resorting to decimals, since 1 millimeter is only slightly more than 1/32 of an inch. However, when precision is required, dimensions are given in decimals of a millimeter and usually in hundredths of a millimeter (for example, 0.04 mm, which is equal to 0.0016 of an inch). Normally, dimensions will not require greater accuracy than to hundredths of a millimeter since 0.01 millimeter is equal to 0.0004 inch.

During the period of transition to the metric system, the first aspect of the new system will probably be the dual-dimensional drawings and prints. In other words, the decimal inch dimensions will be specified and the metric equivalent of it will be entered next to it and in parentheses. For example, .25 (6.5) would be interpreted as 25 hundredths of an inch or 6.5 millimeters. Notice that the metric dimension is understood to be in millimeters. Threads will appear *either* in the metric designation or in the familiar National Course or National Fine designation. This single designation is used because most thread sizes are not compatible from one system to the other. A typical metric thread designation would appear as follows: M5X.8-6H/6g. The "M" denotes a metric screw thread in the British Standard System. The "5" is the nominal diameter in mm, "0.8" is the thread pitch in mm, and the "6H/6g" refers to the tolerance class designation.

When diameters are dimensioned in the metric system, a sybmol is used in place of the familiar "DIA." For example, 9.52 mm diameter would appear as 9.52 ⊖ *not* as 0/52 DIA.

Exercises (025):

1. What two units of metric measure will you probably use most as a machinist?

2. Convert 12.39 millimeters to inches.

3. Convert 3.5 inches to millimeters.

4. Why does a metric dimension expressed in hundredths of millimeters usually provide sufficient accuracy for drawings related to your work?

5. How would a diameter of 8.40 millimeters be designated on a metric drawing?

4-3. Sketching Shop Drawings

If you have ever watched a skilled surgeon operate, you noted that he used each tool strictly for its intended purpose. As a skilled machinist, you too must use each tool for its intended purpose. In your career field, you have one advantage that the surgeon doesn't have. You have the capability to change the design of a tool from time to time as the need arises. In order to fully understand how you can use each tool to its maximum, you must know how to use freehand sketching, tolerancing, and dimensioning.

In this section we shall discuss freehand sketching, the tools that you need to do freehand sketching, and the techniques used in developing freehand sketches.

026. Describe the tools, materials, and procedures for constructing shop drawings by freehand sketching.

Freehand Sketching. In CDC 53130 and previous objectives in this chapter, you learned some basic information about blueprints. That information applies to freehand sketches as well as to the mechanical drawings from which blueprints are made. To include information on a sketch or omit it is the decision of the person who makes the sketch. That person must include as much information as he feels is necessary to serve his purpose. The information, given as dimensions or notes, should conform to good drafting standards and practice.

Mechanical drawings are made with mechanical devices, such as the pencil compass, triangle, and T-square. A sketch is usually considered to be freehand, although, in practice, it is often made on squared paper or with the help of a rule and a pencil compass. Usually a sketch is made of an existing object, but it can also be an "idea" sketch of something only thought about, or a combination of both..It can be drawn pictorially, so that it acutally looks like the object, or it can be an orthographic sketch of the object with different views, usually front, top, and side. It can be either an assembly sketch or a detail sketch. An assembly sketch, as the name implies, shows two or more parts fastened together to form a unit. A detail sketch shows one single part of an assembly in detail.

Freehand sketching tools. Some of value in freehand sketching, in addition to the fact that it is an excellent way to present your ideas to someone else, lies in the fact that so few tools are necessary. If you have a stub of a soft pencil (HB or F) and a scrap of paper handy, you are ready to go. However, a pencil long enough to permit a relaxed but stable grip improves your sketching. For most sketching, you hold the pencil exactly as you do when you are writing. If you are sketching a circle, you may find it easier with the pencil below your hand and held against your four fingers with your thumb. If erasing is needed, the eraser at the end of some pencils is, of course, convenient and safisfactory for limited use. The soft end of a pencil-and-ink eraser, however, is better, and artgum and pink pearl erasers are best. They do a cleaner job of removing pencil lines from paper.

If you need to use a pencil compass, the inexpensive kind costing about a quarter at stationery stores is all that you need. Almost any kind or size of rule can be used as a straightedge. As your ability to sketch improves, you may find that you use the compass and straightedge less and less until you no longer need them to produce neat and effective sketches quickly. The ability to do completely freehand sketching is the ideal situation, which some people reach before others.

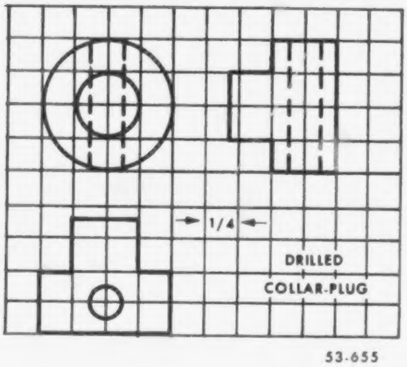


Figure 4-24. Use of cross-section paper.

Just as preparing rough sketches without instruments saves time, the use of cross-section paper also saves time. Cross-section paper, which is usually ruled in 1 inch squares, is especially useful when you sketch to scale. These squares can then be subdivided into 1/8- or 1/10-inch squares. Note that the person who made the sketch in figure 4-24 has indicated that each square represents one-fourth inch. A specially ruled isometric paper, shown in figure 4-25, is used to make isometric and oblique sketches. This type of ruled paper is helpful in making other shapes, such as those shown in figure 4-25, and is often a great help in developing the ability to sketch well.

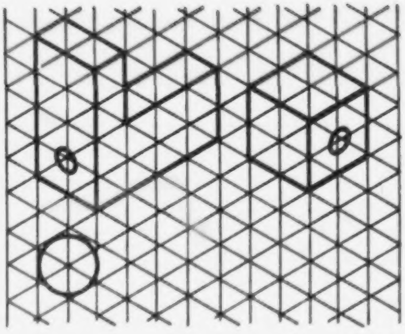


Figure 4-25. Use of specially ruled isometric paper.

Technique of sketching. Hold the pencil from three-quarters to 1 inch from the point so that you can see what you are doing. Strive for a free and easy movement, rather than a cramped finger and wrist movement. In freehand pencil sketching, draw lines with a series of short strokes, instead of trying to draw each line with one stroke. If you use short strokes, you can better control the direction of the line and the pressure of your pencil on the paper. In sketching lines, place a dot where you want the line to begin and another where you want it to end. In sketching long lines, place on or more dots between the end dots. Then swing your hand in the direction the line should go and back again a couple of times before you touch the pencil to the paper. In this way, you get the feel of the line. Then use the dots to guide your eye and your hand as you draw the line. Try drawing several light horizontal lines and, after each one is drawn, examine it for straightness, weight, and neatness. If it is too light, you need either a softer pencil or a little more pressure.

Vertical lines are usually sketched downward on the paper. The same suggestions for locating dots and using a free movement of the entire arm apply to vertical lines as well as to horizontal lines. Slanting lines can be drawn from either end toward the other.

With only horizontal lines, vertical lines, and slanting lines, it is possible to make any number of complete and acceptable freehand sketches, depending, of course, on the item or job to be sketched. Keep your freehand sketch neat. To do this, first sketch the line lightly. Lines that are not essential to the drawing can be sketched so lightly that it is not necessary to erase them. Darken essential lines by running the pencil over them with more pressure after you have first drawn them lightly.

Freehand sketches frequently include many circles and arcs. You don't need to be gifted with artistic talent to draw good circles if you follow these suggestions. Referring to part A of figure 4-26, observe how the pencil is held beneath the four fingers with the thumb. This grip produces a "soft" or "easy" motion for sketching large circles, as shown in figures 4-26,B, and 4-26,C. Note in figure 4-26,B, that the second finger rests at the center of the circle and forms a point about which the pencil lead can swing. The distance from the fingertip to the pencil lead determines the radius of the circle. For smaller circles, a somewhat different grip on the pencil is necessary, as shown in figure 4-26,C, but the principle is the same.

Figure 4-26 shows the proper way to grip the pencil; figure 4-27 shows how to draw the circles by using these grips. As shown at part

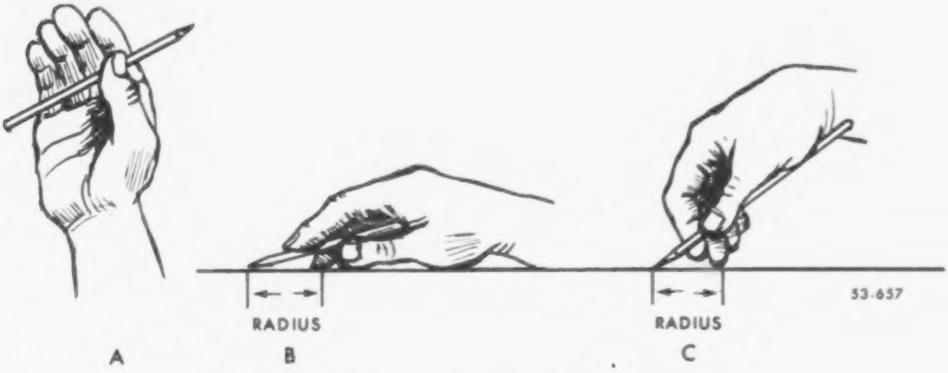


Figure 4-26. Pencil grip for drawing circles and arcs.

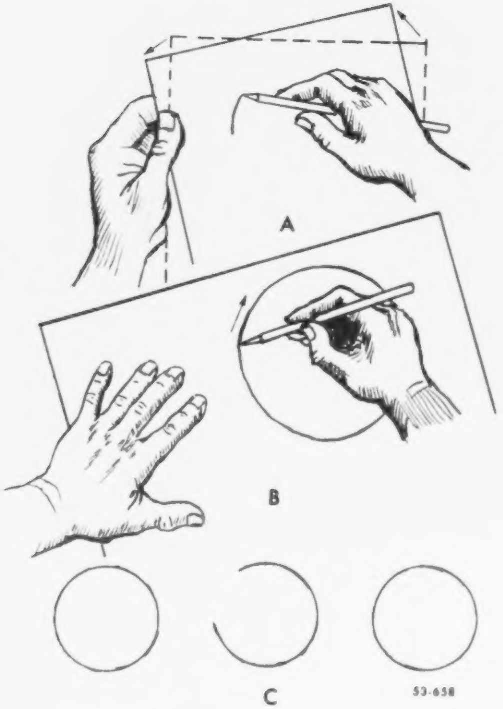


Figure 4-27. Sketching a circle.

A in figure 4-27, the first step in sketching either large or small circles with the grips shown in the previous figure is placing your second finger on the paper at the center of the proposed circle. Then, with the pencil lightly touching the paper, use you other hand to rotate the paper to give you a circle that may look like the one in figure 4-27,B. To correct the slight error of closure shown in 4-27,C, erase a substantial section of the circle and correct it by eye. You now have complete and round circles but with a very light line that must be made heavier. Darken the line by using the technique shown in 4-27,B. Note that you do not pivot on the second finger during this step. Rest your hand on its side, keep it within the circle, and trace over the light line with your hand pivoting naturally at the wrist. As you work around the circle in this way, rotate the paper counterclockwise so that your hand can work in the most natural and easy position. With smaller circles you cannot, of course, work with your hand within the circle, but the same general approach can be used with success.

Exercises (026):

1. List the minimum tools required to sketch a shop drawing.

2. What types of erasers are best for shop sketches?

3. What standards should apply when you begin dimensioning your sketch?

4. Specially ruled isometric paper is best suited for which two kinds of sketches?

5. When sketching lines, what can you do to aid in ending them at the right place?

6. Explain the first step in sketching circles.

CHAPTER 5

Hand and Special Tools

DURING YOUR training to the 3 skill level, you were introduced to many large and complicated machines, such as lathes, milling machines, etc. You learned that these machines must be used and cared for properly for them to be safe and to do the job that they were designed to do. But did you ever stop to think that simple items such as handtools must also be properly used and cared for? Most people don't think about it at all; in fact, more handtools have to be replaced because of misuse than because of normal wear. This chapter will help to refresh your memory of some techniques for using and caring for various hand, precision measuring, and special tools, as well as review some procedures for work layout. As you study this material, remember that *any* tool can be dangerous if it is used improperly.

5-1. Common Handtools

In this section, we shall discuss the use and care of some of the many common handtools, both metal-cutting and nonmetal-cutting, that you will be using. Also, we shall look briefly at various measuring devices and at several pneumatic tools.

027. Indicate the correct usage and care of hammers, punches, and chisels.

Hammers. Many people are injured and many parts are damaged each year because of improperly used hammers. One of the first things that you should do before using a hammer is to check the head to be sure that it isn't loose. When the head of a ball peen hammer comes off during a hitting stroke, it can cause severe injuries or damage to equipment. When you find on ethat is loose, fit it before you use it or turn it in to supply for a new one if it cannot be repaired. At any rate, don't put it back in the toolkit or shadow board in the unserviceable condition; the next person to use it might forget to check it.

The next thing that you should check for is nicks and burrs on the hammerhead face. If any are found, you should regrind the face sufficiently to remove them. Otherwise, they could cause the hammer to glance off the objecet that you were hitting—and that usually means a smashed finger!

Punches. Usually, hammers are used in conjunction with another tool, such as a punch. There are three types of punches that are

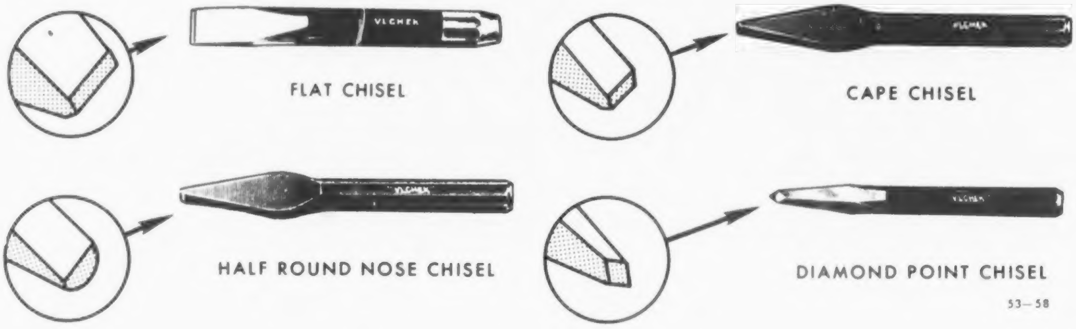


Figure 5-1. Chisels.

normally used in the machine shop. They are the prick punch, the center punch, and the drive pin punch. The only real difference between the prick punch and the center punch is the included angle of the point. The prick punch has a long, slender point with an included angle of 60° and is used mainly for making fine punch marks along layout lines for easy location during machining. The center punch normally has an included angle of 90° and is used to deepen prick punch marks prior to drilling. Always check the point of center and prick punches prior to use. You can't make an accurate punch mark with a dull or broken punch. Also, check the driving end. Any burrs or mushroomed effect must be ground off before you use these punches.

Drive pin punches do not normally have a point but instead are flat on the working end. They are used as drifts for removing various types of pins and bolts. They are made in nearly any diameter and can be locally produced to exact requirements when necessary. When using a drive pin punch, you should use the largest-diameter punch that will follow the pin or bolt into the hole without binding. Remember too that a series of light taps with the hammer is usually better than heavy blows, at least to start with. A heavy blow will more often bend the punch or mushroom the end of the pin or bolt instead of moving the pin. Be sure that both ends of drive pin punches are ground flat and free from burrs before using them, regrinding them, if necessary, when you finish with them. *Don't* put them away in unserviceable condition.

Chisels. Another tool that is used in conjunction with the hammer is the chisel. As you know, chisels are metal-cutting tools and have a sharp cutting edge. They will cut any material that is softer than the chisel (including fingers!), so be careful how you handle them. As shown in figure 5-1, chisels come in different shapes and sizes.

Chisels should be ground with an included angle of 60° to 70°. The cutting angle may vary between these limits according to the strength of the material to be cut. Chisels used on hard or tough metals require a stronger cutting edge (70°), while a faster and cleaner cut can be made through softer metals with chisels ground to a sharper (60°) angle. If you also grind flat chisels to a slightly convex cutting edge, there will be less tendency for their corners to dig into the surfaces that are being chiseled. This method of grinding also focuses the impact at the center of the cutting edge where there is more material to withstand the strain than at the corners.

When you use a chisel, watch the cutting edge of the chisel rather than the head end. With a little practice, you can soon acquire the knack of striking the head of the chisel without looking at it. By watching the cutting edge of the chisel, you can control the direction and depth of cut much better.

Just as with punches, *never* allow a mushroom head to form on a chisel. The head end should be ground flat and have a beveled edge to prevent particles from flying off and possibly causing injury.

Exercises (027):

1. List two commonly overlooked conditions that can cause a hammer to become dangerous and unserviceable.

2. What is the main difference between a center punch and a prick punch?

3. What is a good rule of thumb when you are selecting a drive pin punch for a particular job?

4. Why is it better to start with a series of light taps on a drive pin punch than to begin with a hard blow?

5. At what included angle should chisel be ground in order to best cut hard or tough metals?

6. What should you always do prior to using either punches or chisels?

7. What should you focus your eyes upon while using a chisel?

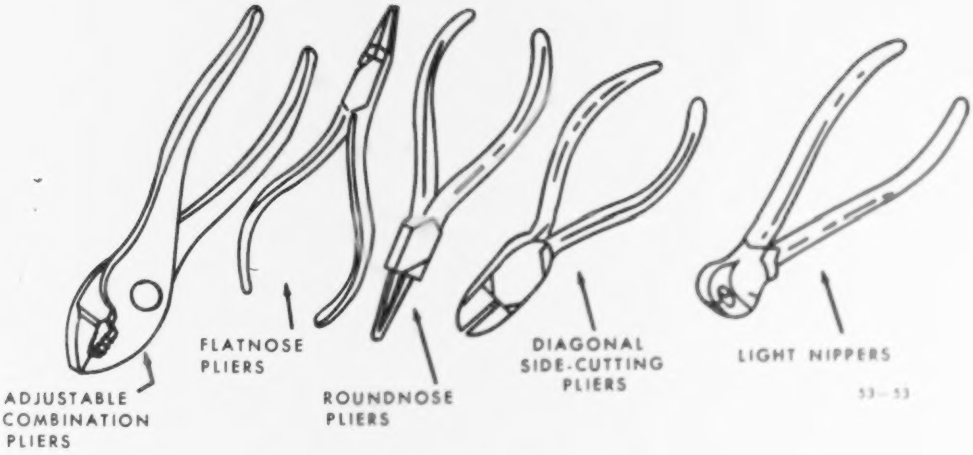

FLATNOSE PLIERS
ADJUSTABLE COMBINATION PLIERS
ROUNDNOSE PLIERS
DIAGONAL SIDE-CUTTING PLIERS
LIGHT NIPPERS
53-53

Figure 5-2. Pliers.

028. Indicate the correct usage and care of screwdrivers, pliers, and wrenches.

Screwdriver. As you know, there are several types of screwdrivers (common or flat-tipped, cross-point, offset, etc.) and many different sizes in each type. This fact causes the screwdriver to be misused by all too many people—even people who supposedly know better. Always select the screwdriver that most accurately fits the slot of the screw. Too large a screwdriver will slip out of the screw slot and damage the screw. Too small a screwdriver will spin in the slop and strip it out or cause damage to the screwdriver tip. You should never use a screwdriver with a damaged tip: it can easily slip or break under pressures, causing damage to the screw or the surrounding area or even a painful hand

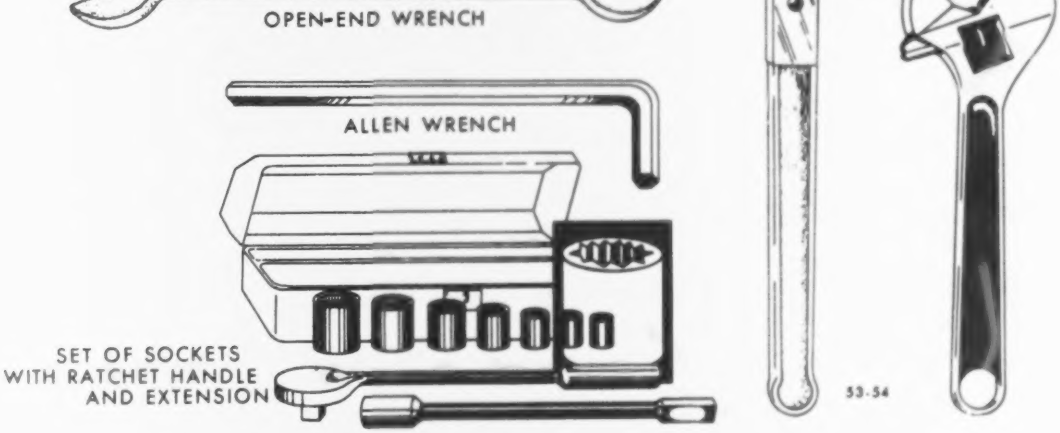

PIPE WRENCH
BOX-END WRENCH
ADJUSTABLE OPEN-END WRENCH
OPEN-END WRENCH
ALLEN WRENCH
SET OF SOCKETS WITH RATCHET HANDLE AND EXTENSION
53-54

Figure 5-3. Wrenches.

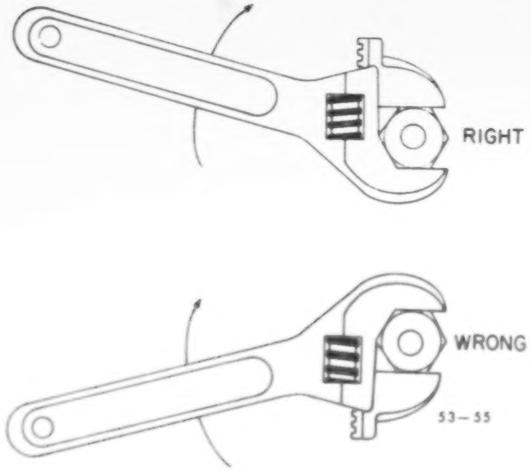


Figure 5-4. Direction of force in using an adjustable wrench.

injury. NOTE: Screwdrivers are not to be used as prybars either! The tip of the common or flat-tipped screwdriver can be easily reground when it becomes nicked; however, be careful not to overheat it during the grinding operation as overheating will pull the temper out of it and render it useless.

Pliers. As with screwdrivers, there are many types of pliers, and each type was designed to do a particular job better than the other types. Some of the different types are shown in figure 5-2. When you use pliers, be sure to wipe any oil film off the handles first. Also, be sure to grip well back of the pivot joint. This hand position will give you maximum pressure at the jaw's working end and will also keep you from pinching the skin on your hand between the handles. Never use pliers when you can accomplish the job with a wrench. The teeth of the pliers will quickly mar or damage a nut or finished object. Normally, the jaws of pliers should not overlap each other when closed. If they do, you can hold them in a closed posiion and grind the tips until they are even. When you use side-cutting pliers or the cutting edges on certain other types of pliers, don't try to cut anything that is too hard to file easily. Such cutting jobs will damage the cutting edges.

Wrenches. Several of the more common types of wrenches are shown in figure 5-3. Of those shown, the adjustable wrench and the Allen wrench are the two that you will probably use most.

The adjustable wrench comes in several sizes, which are determined by the length of the handle. As with any tool, there is a right way and a wrong way to use it, as shown in figure 5-4. Notice that in the wrong method the pressure or force is on the movable jaw which is the weakest part of the wrench. Under heavy pressure, this jaw can spring enough to allow the wrench to slip off the nut, and that action usually leads to skinned knuckles. It would be difficult to formulate a hard and fast rule for selecting the correct size of adjustable wrench because of the varied circumstances under which they are used. However, a good rule of thumb is to use the smallest one that will fit the nut. The reason for this is that the bigger the wrench, the more chances there are of breaking the bolt or stripping either the bolt or the nut.

An Allen wrench is six sided, L-shaped, and designed to fit into the recessed head of a setscrew or capscrew. Either end of this wrench will fit into the recess, making its use possible where either a long or short reach is desirable. Allen wrenches are not designed for work when a fairly high amount of torque is needed. In fact, if you apply excessive torque, a small Allen wrench will snap; and a larger one will bend out of shape and perhaps break. An Allen wrench should not be used if its corners are worn, as this condition can damage the recess in the screw. A damaged recess in the screw can make removal of the screw with the Allen wrench difficult or impossible.

Another wrench that you might use (not pictured) is the torque wrench. Torque wrenches are calibrated tools used to measure the force of pull (pounds) when you are tightening nuts or hose clamps or checking the breakaway torque of various driving units. The torque is expressed in either inch-pounds or foot-pounds. There are two basic types of torque wrenches. The indicating type indicates the amount of torque being applied, either on a dial or by means of a pointer. The breakaway type is more commonly used by the Air Force. This type automatically releases when a predetermined torque value has been reached. You should always check the calibration date on a torque wrench before using it. If it is past due, it should be recalibrated before it is used again. Also, if a torque wrench is dropped, it should be recalibrated. When you use a torque wrench, *don't* use an extension on the handle, since the torque value will *not* be the same as indicated. Torque wrenches should not be used to loosen nuts, as this use could damage the wrench. Also, a torque wrench should always be reset to its lowest torque setting before being stored.

Exercises (028):

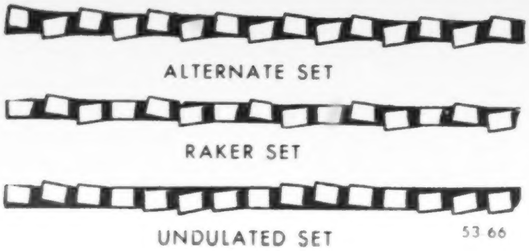

ALTERNATE SET
RAKER SET
UNDULATED SET
53.66

Figure 5-5. Set of hacksaw blade teeth.

1. What can happen if too large a screwdriver is selected for a particular size of screw slot?

2. Which type of screwdriver can be easily repaired if the tip becomes nicked or rounded? Explain how.

3. Where on the handles of pliers is the best place to grasp when you are using them?

4. State the rule to follow when attempting to cut metal with pliers.

5. When turning a nut with an adjustable wrench, why shouldn't the pressure be against the movable jaw?

6. Why should you choose a smaller adjustable wrench to start with even though a larger one is available?

7. What can happen if an Allen wrench is used with worn or rounded corners?

8. List the two basic types of torque wrenches.

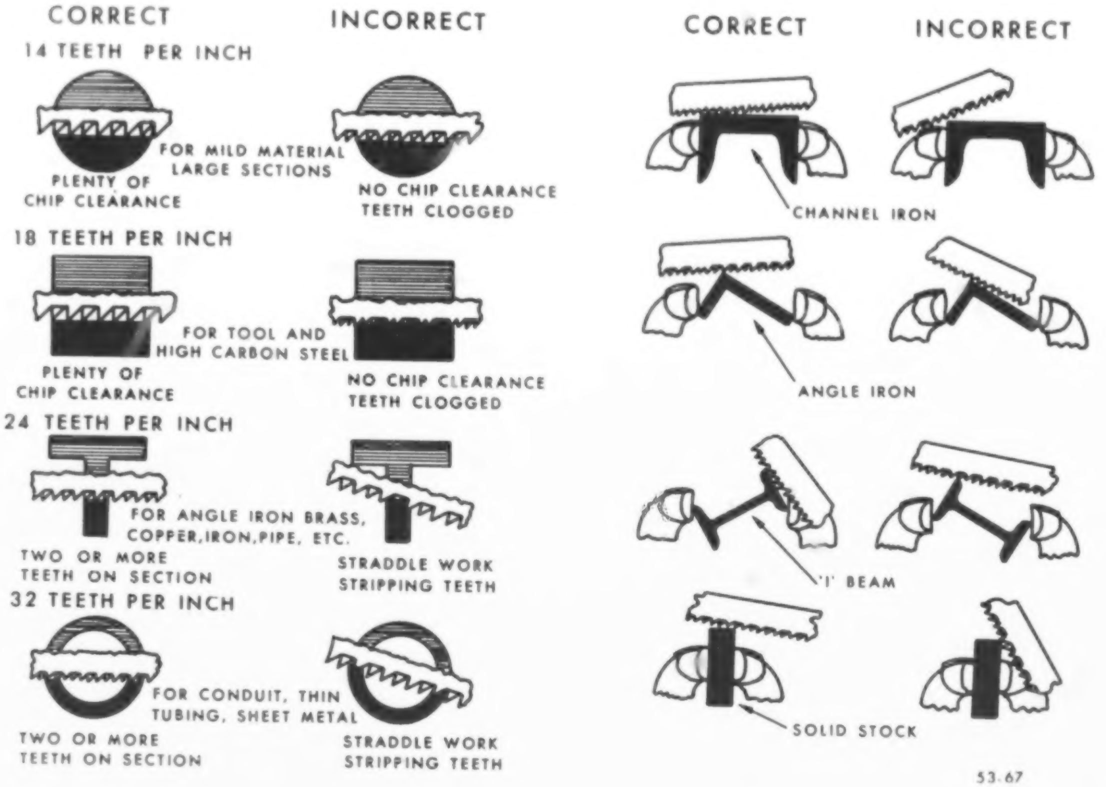

CORRECT
INCORRECT
14 TEETH PER INCH
FOR MILD MATERIAL LARGE SECTIONS
PLENTY OF CHIP CLEARANCE
NO CHIP CLEARANCE TEETH CLOGGED
18 TEETH PER INCH
FOR TOOL AND HIGH CARBON STEEL
PLENTY OF CHIP CLEARANCE
NO CHIP CLEARANCE TEETH CLOGGED
24 TEETH PER INCH
FOR ANGLE IRON BRASS, COPPER, IRON, PIPE, ETC.
TWO OR MORE TEETH ON SECTION
STRADDLE WORK STRIPPING TEETH
32 TEETH PER INCH
FOR CONDUIT, THIN TUBING, SHEET METAL
TWO OR MORE TEETH ON SECTION
STRADDLE WORK STRIPPING TEETH
CORRECT
INCORRECT
CHANNEL IRON
ANGLE IRON
'I' BEAM
SOLID STOCK
53.67

Figure 5-6. Selection of pitch.

9. Why shouldn't you use an extension on the handle of a torque wrench?

10. What should you do to a torque wrench before you put it away after using it?

029. Explain the procedures for selecting hacksaw blades and using the hacksaw.

Blade Selection. You should carefully select the proper blade for each cutting purpose. Hacksaw blades are made of a high-grade tool steel that has been hardened and tempered. An all-hard blade is hardened throughout; a flexible blade has only its teeth hardened and will, therefore, not break as easily under bending stresses. Use an all-hard blade for sawing brass, tool steel, cast iron, and other stock of heavy cross section. Use a flexible blade for sawing hollow shapes and metals of light cross section, such as channel iron, tubing, tin, copper, aluminum, or babbit.

"Set" is the angle (or angles) at which the teeth of the blade are set to provide clearance for the rest of the blade in the saw cut. You will notice, if you look at various hacksaw blades, that the blades with coarse teeth have one tooth moved slightly to the right, the next one to the left, the third one to the right, etc. This arrangement is the standard, or alternate, set. (See fig. 5-5.) Medium-coarse teeth may be bent in a raker set (one right, one left, one straight, etç.) , while fine-toothed blades usually have an undulated set (whole sections of teeth alternately bent to the right or left). Carpenters reset the teeth of their woodcutting saws from time to time, but when a hacksaw does not cut well or binds excessively from insufficient set, you discard the blade and insert a new one.

You do not have to worry about the set of a hacksaw because it is built into the blade. However, your judgment in selecting a blade with proper pitch (number of teeth per inch) may well determine how quickly and easily the saw cuts through the material and how long the blade can be used. Blades are made with pitches of 14. 18. 24. and 32 teeth per inch. as shown in figure 5-6. Follow these recommendations for best results:

- Use a 14-pitch blade on machine steel, cold rolled steel, or structural steel. The coarse pitch makes the sawing free and fast cutting.
- Use an 18-pitch blade on solid stock, aluminum, babbitt, tool steel, high-speed steel, cast iron, etc. This pitch is recommended for general use.
- Use a 24-pitch blade on tubing, tin, brass, copper, channel iron, and sheet metal over 18 gage. If you use a coarser pitch, the thin material tends to strip the teeth out of the blade and makes it difficult to push the saw.
- Use a 32-pitch blade on thin-walled tubing, electrical conduit, and sheet metal thinner than 18 gage.
- Select a pitch or manage the sawing so that two or more teeth are usually in contact with the material, as you see in figure 5-6.

Hacksaw Use. A small notch filed at the starting point on the material to be cut will help you to start the saw blade accurately. Apply pressure on the forward stroke and reduce it on the back stroke. The ease with which a piece of metal may be cut depends upon the speed and pressure applied to the saw. A cutting speed of 40 to 50 strokes per minute is best because this speed does not tire you and also permits you to relieve the pressure on the return stroke. Faster speeds will damage thin blades because the heat generated draws the temper and makes the blade soft. Here are some hints that will help you to speed up the sawing and make it easier:

a. Apply a little oil to the sides of the blade with your finger to reduce binding when you are making a deep cut.

b. Take care to prevent either stripping the teeth or breaking the blade. Some of the causes of breakage are a pitch that is too coarse for the material, the application of too much pressure on the cutting stroke, the slipping of work in the vise, and cutting off at an angle and then trying to straighten the cut by twisting the saw.

c. Clamp thin stock between two pieces of wood or soft metal and saw through all three pieces. This technique will prevent annoying chattering and possible damage to the thin stock.

Exercises (029):

1. If you were given a job that required you to saw through a 1-inch brass rod with a hacksaw, what would be the best type of blade to use?

2. Could you cut a piece of 0.040 sheet metal with a 24-pitch blade and still insure that two teeth are in contact with the material? Explain.

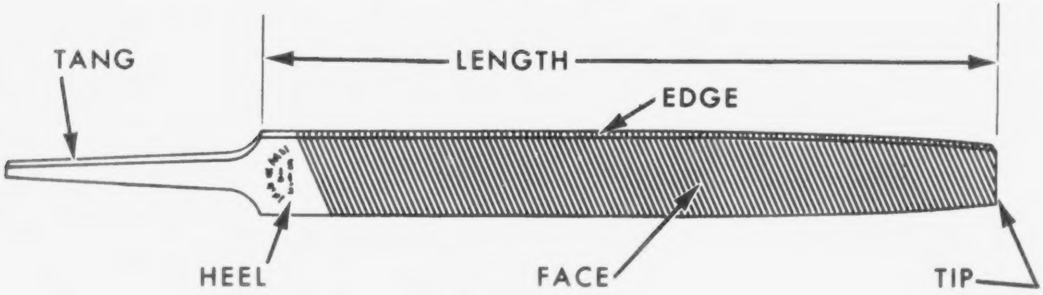


Figure 5-7. File parts.

53-59

3. Given the task described in exercise 2, what pitch blade would be the best selection for the job?

4. What can you do to prevent the blade from sliding around on a piece of stock when starting the cut?

5. What are the possible results of applying too much pressure on the cutting stroke?

030. Identify various kinds of files and scrapers, and describe their use and care.

Files. Even though you probably learned about files during your 3-level studies, a good review is in order since files are regularly misused. In fact, for most people, the "right" file for a particular job is usually the handiest one. In those cases, both the file and the job usually suffer.

Files are manufactured in many shapes and sizes. They are identified by their general shape or cross section or by their particular use. Figure 5-7 shows the parts of a file. Figure 5-8 shows the shapes of files. The shape is governed by the cross section. Figure 5-9 shows the various file cuts. Cut refers to both the coarseness (coarse, bastard, second, and smooth) and type of cut (single or double). A

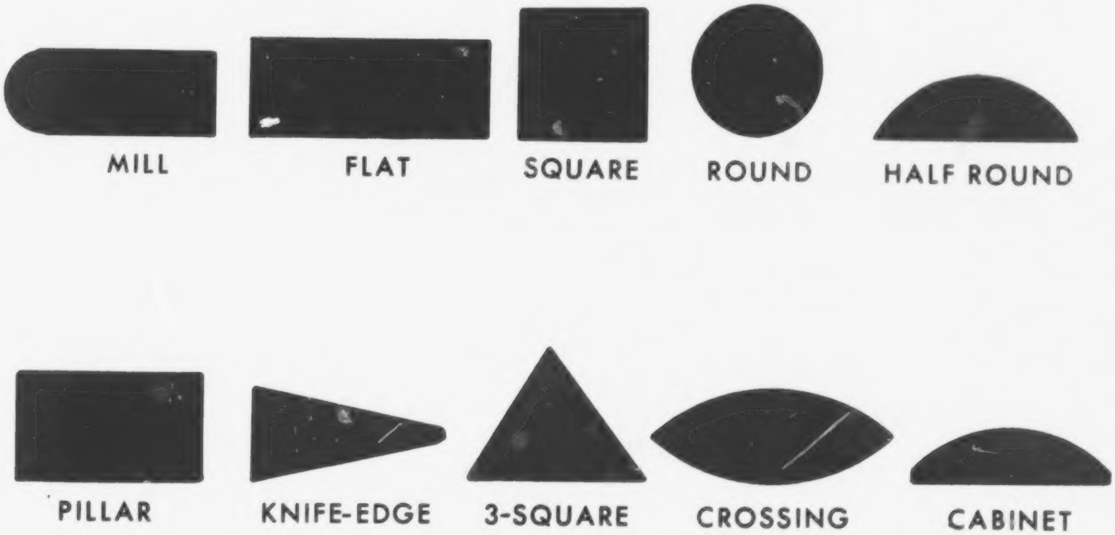


Figure 5-8. Various file shapes.

53-60

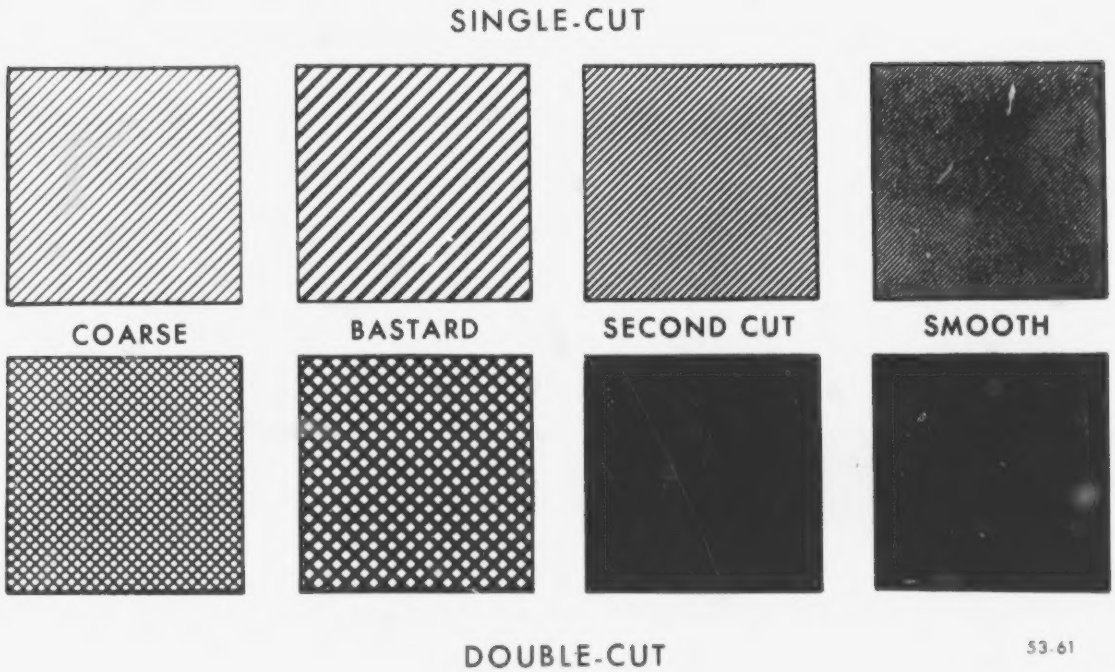


Figure 5-9. File cuts.

double-cut file makes a faster but rougher cut than a single-cut file. A 10-inch bastard file is coarser than an 8-inch bastard because the distance between the teeth increases as the length of the file increases.

For normal crossfiling (conventional), you should reduce the pressure on the back stroke to avoid excessive wear on the teeth. Do not exceed 30-40 strokes per minute. A higher rate may damage the file. Never use a file as a pry or hammer, for it is almost sure to break and either injure you or damage the work.

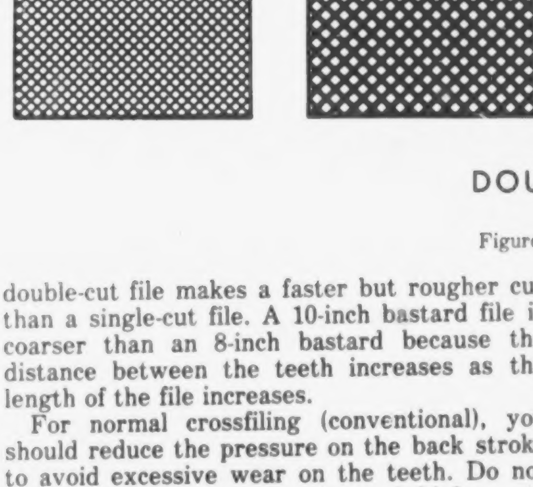

TO ROUND A CORNER
A
B
C
CORNER FILED OR SAWED OFF
CORNER REDUCED BY ROUGH FILING
CORNER ROUNDED WITH A FINE FILE
BACK AND FORTH STROKES
53-63

Figure 5-10. Rounding corners and drawfiling.

Figure 5-10 shows how to round a corner and how to do drawfiling. Drawfiling produces accurate and extremely smooth filed surfaces. CAUTION: *Never use a file without a file handle*. The sharp tang can easily penetrate your hand if the file should slip.

Use a file brush and card to clean the file and to prevent scratching the work surface due to "pinning" (the lodging of metal particles in the file teeth). Be sure to clean the file often during use. Also, never place files in contact with each other, as contact can quickly damage the file teeth.

Some of the more common types of hand files and their uses are as follows:

Flat files are tapered slightly toward the point in both width and thickness. They are double-cut on both sides and single-cut on both edges. They are available in bastard, second-cut, and smooth cuts and are used for all common filing operations.

Mill files are tapered slightly in thickness and width for approximately one-third of their length. They are single cut in bastard, second cut, or smooth cut. Mill files are available with square edges and with one or two round edges for filing gullets between saw teeth. They are used mainly for sharpening mill or circular saws, edge tools, and machine knives. They are also used for lathe work, for drawfiling, and for finishing brass and bronze.

Half-round files are not complete half-circles as the name implies, since the arcs are about one-third of a circle. They are available in nearly all cuts. They are double cut, tapered in width and thickness toward the point, and have one flat and one oval side. They are used primarily for filing concave surfaces.

Round files, often called rattail files, are circular in cross section, are tapered or blunt, and are single or double cut. They are made in bastard, second cut, and smooth cut. Round files are used mainly to file or enlarge circular openings or to file concave surfaces.

Square files are square in cross section, are tapered or blunt, and are double cut on all four sides. They are made in bastard, second cut, and smooth cut and are used for filing keyways. slots, corners, and general surface filing.

Three-square files, often called triangular or three-corner files, are triangular in cross section, are tapered or blunt, and have sharp edges. They are double cut or single cut and are made in bastard, second cut, and smooth cut. They are used to file acute internal angles, to clear out square corners, and to repair damaged threads.

Knife-edge files are shaped like knife blades. They are double cut on both sides and single cut on its one edge. Knife files are made in bastard, second cut, and smooth cut and are used for filing V-grooves and narrow slots.

Pillar files are of even width, are tapered in thickness, have one "safe" (uncut) edge, and are narrower than most hand files. They are used mainly for filing keyways and slots.

Curved-tooth, or vixen, files are widely used for smooth, rapid filing of cast iron, bronze, lead, babbitt, aluminum, zinc, plastics, and sheet metal. The curved teeth readily clear themselves of chips.

Lead-float files are used especially for filing lead, babbitt, and other soft metals. They have coarse, short-angle, single-cut teeth that shear away the metal rapidly under ordinary pressure.

Hand Scrapers. Hand scrapers are tools that are used to remove high spots from machined surfaces. In order to produce an accurate, flat bearing surface, you must locate and scrape off the high spots. You also scrape bearings for close running fits for shaft bearings.

Hooked scraper (flat surfaces). The hooked scraper is used for the "flowering" or "frosting" design you see on scraped surfaces. You also use the hooked scraper for scraping surfaces when it is inconvenient to use the flat scraper. An application of the hooked scraper would be the angle of a dovetail bearing surface. You may need to scrape round or curved surfaces to obtain good running or sliding fits, which demands another type of scraper.

Half-round bent scraper. The half-round bent scraper is the most common used scraper for curved surfaces. It has two cutting edges. The cutting stroke may be either toward or away from you.

Hooked scraper (curved surfaces). The hooked scraper is preferred by many craftsmen. It is used for scraping larger surfaces. You grind the cutting edge to conform to the curve of the work. Then you sharpen the scraper to cut on the pull stroke.

Three-cornered scraper. The three-cornered scraper is used to break (remove) the edges of holes or edges or other curved work. The three-cornered scraper may also be used to round the corners. The three-cornered scraper is usually made by grinding off the teeth of an old file. This produces three cutting edges. The three corners of the body back of the cutting edge should be well rounded to prevent cutting your hands.

Using the Scraper - When you need to hand scrape work, you must first locate the high spots on the work. Do this by using venetian red or prussion blue. For flat work, rub a light coat of the red or blue on the surface plate. The surface to be scraped is then rubbed on the surface plate, and you can see the high spots plainly marked with the paint. High spots on bearing surfaces can be found in a similar manner. You apply the shaft to the bearing surface, and the high spots in the bearing are indicated by the red or blue spots. Mating parts are used in the same way to find the high points. As you scrape the high points, the spots increase in number and decrease in size. When this occurs to the point at which the red or blue becomes difficult to use, you can then use turpentine to locate the high spots. The turpentine causes the high points to show up as bright spots. The turpentine also makes the scraper work better.

When you use the flat scraper, the cutting stroke is the forward stroke. The stroke is seldom over one-half inch in length. As you make successive scrapings of a spot, the direction of the strokes should be parallel to one another. The operations using the hooked scrapers are quite similar. The cutting strokes on these scrapers are normally toward you.

While you are scraping, do not allow any oil, or even your fingers, to touch the surface. Be extremely careful that you do not allow any foreign matter to get on the surface plate or the parts: it will impair the checking of the surfaces. When you are roughing the surface, you should scrape fairly hard. As the spots become smaller, ease up on the chip. Dipping the scraper in turpentine will help you to scrape easier and faster. Keep the scraper sharp by occasional sharpening on the grinder and oil stone. A dull scraper will scratch the work.

Exercises (030):

1. What is the difference, besides length, between an 8-inch single-cut, smooth file and a 10-inch single-cut, smooth file?
2. What does pinning mean?
3. Are "flat" files single or double cut?
4. What kind of file has a "safe" edge? How is it used?
5. Which two types of files are well suited for filing lead?
6. What type of scraper is usually used when curved surfaces must be hand scraped?
7. How can you locate the high spots on a flat work surface that needs hand scraping?
8. How can you tell whether you are doing a good job of scraping?

031. Explain the use and care of common machinist measuring devices.

Nearly everything that you do as a machinist will require some sort of measurement. For that reason, many different items have been developed for accomplishing these measurements. We shall examine several of the nonprecision types here.

Steel Rule. Normally, steel rules or scales come in 6- or 12-inch lengths (although a few other lengths are available) and they usually contain four separate scales; one on each edge. When all four scales are included, one side of the rule contains a 1/8-inch scale and a 1/16-inch scale. The other side of the rule contains a 1/32-inch scale and a 1/64-inch scale. Steel rules are also available with the graduations marked off in decimals or in metric measurements. Some rules have a hook on one end, which allows measurements to be taken from the edge of an object more accurately.

With practice, you can become proficient enough in reading a steel rule that you will be able to approximate, with a fair degree of accuracy, dimensions with a tolerance of less than 0.015 inch, which is the smallest marked graduation. However, when more than a good approximation is required, don't chance a mistake; use a measuring device designed to accurately measure in thousandths or better (micrometers, Vernier calipers, etc.).

Simple, but very effective, accessories are available for steel scales. These accessories greatly extend the usefulness of the scale.

Sliding head. The sliding head has a flat reference surface from which measurements are made. It has a thumbscrew clamp to secure the scale. Normally, the head's reference surface is held perpendicular to the scale by a hand slot or guide pins. The sliding head attachment allows you to use the rule as a depth gage. You would use this attachment to measure the depth of holes and grooves. You can measure the depth of holes and slots up to 5 inches with a 6-inch scale. You can substitute the scale with a 5/64-inch diameter rod for measuring depths greater than 6 inches. An angle index mark is engraved on one side of the conical rule clamp turret; this allows you to use the attachment as a combination protractor to measure approximate angles.

Right-angle clamp. The right-angle clamp is an accessory often used with the combination square. The right-angle clamp holds a scale at a right angle to the blade of the combination square, allowing you to make measurements when both depth and lateral coordinate dimensions are required. When you use the assembly on the surface plate, you can use it as a height gage. You will find many more similar uses of the right-angle clamp.

Keyseat clamps. When keyseat clamps are applied to the steel scale, you have a keyseat rule. The clamps are easily put on and taken off the scale, which is usually a 6-inch scale. When so arranged, they form a box square. The keyseat rule is a very useful tool when you apply it to cylindrical work. You can easily scribe parallel lines on cylindrical work. Also, this device is very convenient in making keyseat layouts on shafts.

Depth Gage. A depth gage is usually a narrow, flat, graduated 6-inch scale attached to a flat, sliding head. On the head is a thumbscrew, which is used to lock the head in position on the scale. The scale is normally graduated in 1/32- or 1/64-inch increments.

Depth gages are used to measure the depth of holes, grooves, slots, etc. As with the steel rules, they are not meant to provide a high degree of accuracy.

Caliper Rule. The caliper rule is a type of measuring caliper. When you use a graduated rule, you have to judge the position of the rule datum edge. It is also necessary that you judge the relation of the graduation to the point being measured by eye. This judgment can lead to error. Greater accuracy is obtained if the measuring device makes contact with the two points being measured. The caliper rule does this. The caliper rule has a graduated scale, a fixed jaw, and a movable jaw. The movable jaw can be moved to make contact with the work. As with the micrometer or calipers, you must also develop a feel for using the caliper rule. When you have the feel of the caliper jaws to the work, you simply read the measurement indicated by the sliding jaw. Caliper rules are constructed to enable you to take both inside and outside measurements. There are two index marks on the movable jaw. Each is labeled as to its function, for outside or iside measurements. To read the dimension, measuring an outside diameter, you would read the dimension indicated by the index mark labeled "out." If you were taking an inside measurement, you would read the dimension indicated by the index mark labeled "in."

Squares. There are several types of squares on the market, but perhaps the most common types for a machinist is the hardened-steel square (toolmaker's square) and the combination set.

Hardened-steel square. The hardened-steel square is produced in a variety of sizes, but the 4 1/2-inch blade is probably the most common. It is used for checking parts for squareness and not for linear measurement. It does not have graduated scales on it. This square is accurately machined to be square and has true right angles inside and outside. This tool is intended to be a very accurate tool, but many people, unfortunately, do not treat it that way. The blade of this square is mounted solidly in the base, but it can be sprung out-of-square if it is dropped. Great care must be taken to prevent nicks in the blade edges as they can destroy the tool's accuracy.

Combination set. The combination set is really much more than a square. It consists of a 12-inch steel blade, normally with four scales from 1/8 to 1/64 inch, and a square head, a center head, and a bevel protractor. The square head, in combination with the blade, can be used to check for squareness, to check 45° angles, or to serve as an adjustable hook for making measurements with the scales on the blade. It can also be used as a depth gage and as a level.

The center gage is used with the blade to locate the center or round stock or other circular objects. The blade splits the 90° angle of the head in half.

The bevel protractor can be used with the blade to check angles. The head can be rotated through 180° and is graduated accordingly. It can be locked in any angular setting by means of two thumbscrews and can slide along the blade and be locked at any required position along the blade's length. This head also has a level gage in it.

Needless to say, the combination set must be treated with care if it is to remain accurate and useful. If properly cared for and used, it can be one of the most useful tools in the shop.

Dividers and Calipers. The most common type of divider and caliper in the Air Force is the spring-joint type. This type is sprung in the open position but has an adjusting screw that can hold the arms in any position within the limits of arm movement. The size of both dividers and calipers is usually the length of the arms.

Dividers. Dividers are used most for scribing circles and arcs during work layout but can also be used to transfer dimensions from scales to work or to simply compare two dimensions. If the sharp points on the arms of the dividers become dull, they should be resharpened with an oil stone. If a point should break, it can be repaired on a pedestal grinder; however, both points must be ground to equalize their length. After grinding, they should be honed to a fine smooth point. Be careful with dividers because the sharp points can puncture your skin quite easily!

Calipers. Calipers are produced in several styles such as inside, outside, and hermaphrodite. They are normally used in conjunction with steel rules or other types of scales but can be used with micrometers to increase their accuracy.

Inside calipers are used to check internal diameters and the width of slots, grooves, etc., and outside calipers are used mainly to check outside diameters. The accuracy of these calipers depends almost completely on the user. You must develop a "feel" for them to be able to get the same reading more than once. However, once you get the hang of it, you will be able to use them quite accurately. When you take a measurement with them, adjust the arms so that only a slight drag is noticed as you pull them from the work. The heavier the drag, the harder it is to get an accurate measurement.

The hermaphrodite caliper is a combination of an outside caliper and a divider. One leg is pointed like the divider and the other is curved inward like an outside caliper. This caliper is used mainly for work layout purposes, and we shall discuss it in greater detail when we cover layouts later in this chapter.

Exercises (031):

1. Can a steel rule be used to take measurements with a tolerance of plus or minus 0.015?

2. What other measuring tool could the scale and the sliding head attachment take the place of?

3. Which measuring device is designed to measure the distance from the top of a block to the top of a step along the side of the block?

4. Why is the caliper rule usually more accurate than a graduated rule?

5. What is the smallest graduation on a hardened-steel square?

6. What angle can be very accurately checked with a hardened-steel square?

7. Which of the three heads in a combination set can be used to check a 45° angle?

8. The included angle of a chisel could be measured accurately with which parts of the combination set?

9. Explain how to repair a broken point on a pair of dividers.

10. What factors affect the accuracy that can be obtained with inside and outside spring calipers?

032. Explain the use and care of various pneumatic handtools.

Pneumatic Handtools. As the name implies, pneumatic handtools are power tools that are driven by air pressure. They were adopted by the Air Force for use in aircraft maintenance shops instead of electrically powered tools because they do not in themselves have the potential for starting fires or producing electrical shock.

As we mentioned in an earlier chapter, one of the most important points to remember when using pneumatic tools is to regulate the air pressure to not more than 150 psi. Too much pressure can easily damage the tool and can rupture the air hose with surprising ease. You should examine the air hoses before each use to be sure that there are no soft spots or deep scratch marks in them. These flaws could cause air bubbles to form under pressure, balloon out, and eventually rupture.

The pneumatic tools used most by the machinist are the drill motor, the hammer (rivet gun), and the grinder.

Drill motor. Most shops have both the 1/4-inch and the 3/8-inch pneumatic drill motor. The 1/4-inch motor is the one normally carried in line kits and is subject to the most abuse. Rust is one of the worst enemies of the 1/4-inch drill motor, since it is used outside in all kinds of weather. When the tool gets wet, it should be dried completely before it is put away. A light film of rust-preventive material should be applied to the chuck. Also, if the line kit box is wet inside (especially if it has foam inserts for separating the tools), it should be dried thoroughly before tools are allowed to be stored in it again. A few drops of lubricating oil should be put into the air intake fitting once or twice a week (just prior to use) to keep the internal mechanisms lubricated and rust-free.

When you use the drill motor, *don't* try to let your hand take the place of the chuck key. Many machinists pound the chuck open with the heel of their hand and then spin it shut again by gripping the chuck tightly while it is turning. This practice is very unsafe. It can damage the drill motor and cause cuts and bruises on your hand. Keep the chuck key attached to the handle of the motor by a small cord or some type and then use it for what it was made.

Hammer. The pneumatic hammer, shown in figure 5-11, is used by many machinists to speed up the removal of screws. (We shall discuss this procedure in some detail in the next chapter.) Whether or not you have an occasion to use the pneumatic hammer depends, in part, on the type of equipment that your shop normally works on. At any rate, it should be cared for in essentially the same way as the drill motor. Be sure that the tool or rivet-set that you insert into the hammer is free from burrs and fits properly into the receptacle. If you don't, the receptacle can be damaged and the tool or rivet-set can be frozen into the hammer, making its removal almost impossible. Also, *never* operate the hammer until the tool is in contact with the job: the tool can become a dangerous projectile under certain circumstances.

Grinder. The pneumatic grinder is a very high speed tool. Like the other pneumatic tools, it should be lubricated periodically with a few drops of lubricating oil in the air intake. This tool requires an extra amount of precaution when it is used. Wear goggles and a face shield whenever possible. Doing so will protect you from the grinder dust and also from the debris resulting from exploding grinding wheels—and they can break apart easier than most people think. Because of this danger, these grinders should be used in areas relatively free from other personnel or in areas enclosed by some form of curtain or shield. Be sure that the grinder wheel is securely mounted to the arbor (for unmounted-type wheels) and that the arbor is securely locked into the grinder *before* operating it. CAUTION: Because of the fire hazard produced by the grinding sparks, this tool should *not* be used on or near aircraft unless special permission is obtained.

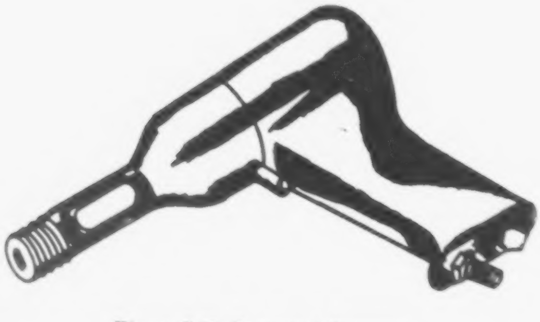


Figure 5-11. Pneumatic hammer.

There are other pneumatic tools in use that we have not discussed here (angle drill motors, sanders, etc.), but the procedures for the care and use of them is typical of the ones that we have discussed.

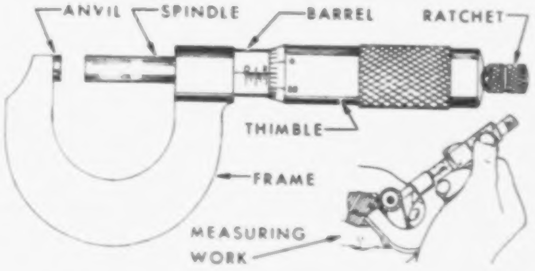


Figure 5-12. Outside micrometer.

Exercises (032):

1. Why are pneumatic handtools preferred over electrical handtools in aircraft maintenance shops?

2. How can the drill motor be protected from rust?

3. How can you be sure that the drill chuck key is always available when you need it?

4. If a burred or damaged rivet set or tool is inserted into a pneumatic hammer, what damage can result?

5. What is one of the biggest dangers involved with using a pneumatic grinder in the shop? How can you protect against it?

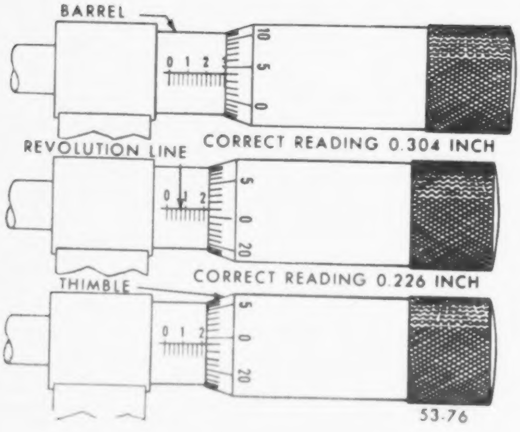


Figure 5-13. Micrometer readings.

6. Why shouldn't the grinder be used on or around aircraft?

5-2. Precision Measuring Tools

In your work as a machinist, you will be required to make many measurements with an accuracy of one- or two-thousandths of an inch or greater. To do this, you will be using such precision measuring devices as micrometers, gages, vernier tools, and dial indicators. In this section, we shall examine the use and care of these tools.

033. Explain the parts of the outside-meter and the procedures for reading and caring for it.

Outside Micrometer. As you probably know, micrometers come in many sizes, each with a range of 1 inch. For example, a 2-inch micrometer has a measuring range from 1 to 2 inches, and a 6-inch micrometer has a measuring range from 5 to 6 inches. The major parts of an outside micrometer are shown in figure 5-12. A micrometer can measure because of the spindle screw. Since this screw has a pitch of 40 threads per inch, turning the thimble 40 complete revolutions moves the spindle exactly 1 inch. A clockwise turn moves the spindle toward the anvil. You can easily understand, then, that a single revolution from one screw thread to the next will move the spindle 1/40, or twenty-five thousandths (0.025), of an inch (1,000 inch divided by 40 equals 0.025 inch). Along the barrel in figure 5-12, you can see the number 2 over the eighth graduation to indicate 2/10 inch (8 times 0.025 = 0.200). In figure 5-12, the thimble has traveled no *full* graduations past the 2 point; therefore the measurement reads 0.200 inch (0.200 inch as signified by the number 2) plus some yet unknown quantity indicated by the spindle having gone past the number 2 graduation. Now look at the graduation on the thimble. Since the circumference of the thimble is divided into 25 equal spaces, each graduation represents 1/1000 inch (0.001 inch). With a reading of 0.200 inch on the barrel and a reading of 23 graduations past the zero point on the thimble, the final measurement in figure 5-12 is two hundred twenty-three thousandths of an inch (0.223 inch). Figure 5-13 shows some additional micrometer settings and readings. Study them until you are certain that you understand how the readings are obtained.

In the illustrations, the graduations on the thimble are always shown as lining up exactly with the revolution line. In many cases, however, you will not find this true in actual practice. If the micrometer does not have a *vernier* scale graduated on the barrel, you will have to divide the distance mentally between thimble graduations into tenths and guess at the number of ten-thousandths of an inch. However, when the micrometer has a vernier scale, as shown in figure 5-14, you can obtain a more precise measurement, because one of the thimble graduations lines up exactly with a vernier scale graduation. This precision is possible because a distance equal to only 9 thimble divisions has been divided into 10

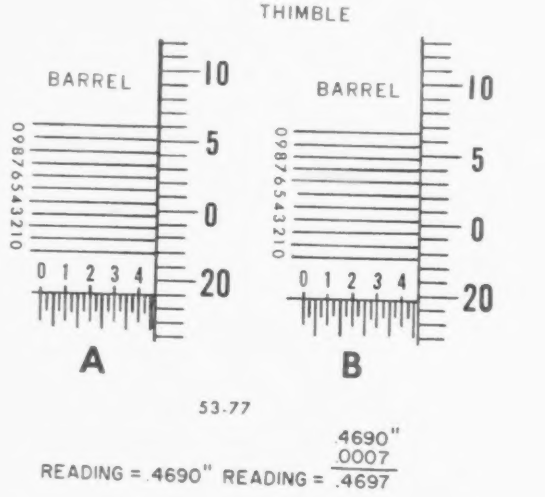


Figure 5-14. Vernier scale.

vernier graduations: each vernier graduation is 1/10,000 inch (0.0001) shorter than a thimble division. Hence, when thimble division 19 exactly matches the barrel revolution line, as shown in A of figure 5-14, the zero graduations at each end of the vernier scale exactly match a thimble graduation. This indicates a reading in exact thousandths of an inch of 0.4690 inch. In figure 5-14,B, the revolution line splits the space between 19 and 20 on the thimble so that we have 0.469+ inch. Looking at the vernier scale, note that line 7 on the barrel exactly matches a thimble graduation; thus the final reading is 0.4697 inch.

When using a micrometer, you must be careful not to drop it or use it roughly. Impacts can cause it to give erroneous and to require recalibration. You can check the accuracy of the 0- to 1-inch micrometer by turning the thimble until it contacts the anvil. When it is properly calibrated, it will read exactly "0" at this point. *Don't* over torque it when you do this: use the ratchet if the micrometer has one; otherwise, use about the same pressure as if you were measuring an object. Also, be sure to clean both the thimble and anvil before turning them together. Tiny dust particles can give erroneous readings as well as scratch the two micrometer parts. The accuracy of larger micrometers can be checked with gage blocks or with standard check rods usually provided by the manufacturer.

Micrometers should not be left lying on work benches or machines when not actually being used unless they are in a closed case or box or some other protective cover that will keep dust and grit from them. If grit and dust collect around the lead screw, it will cause play to develop or cause the spindle to bind in the barrel.

Exercises (033):

1. How many threads per inch does the spindle screw of the micrometer have?

2. How many thousandths of an inch will the spindle move if it is revolved three complete turns?

3. What part of an inch is the space between each pair of marks on the barrel?

4. Each graduation on the vernier scale represents what part of an inch?

5. How can you check the accuracy of a 1-inch micrometer without any other tools?

6. What effect can dust and grit have on a micrometer?

034. State the purpose of telescope and small hole gages, and explain specific aspects about their operation.

Telescope Gage. The telescope gage is pictured in figure 5-15, along with several other gages that you may use as a machinist. This telescoping gage can be used in places in which a micrometer or a vernier caliper would be awkward to handle. With it, you can quickly and accurately obtain the inside measurements of slots or holes. This T-shaped tool consists of an adjusting handle, a mounting head, and two plungers, one telescoping into the other, which can be locked by turning a knurled screw. Although the gage is not calibrated, you can easily read the measurement obtained by checking the telescope gage with a micrometer or a vernier caliper.

Be careful when locking a telescope gage into position. The threads on the lock screw are quite small in most cases and can be stripped easily. Also, check to be sure that the head of the gage is tight on the handle. If it becomes loose, it will allow the plungers to come completely out of the head, which, in turn, allows a tiny coil spring to shoot out of the plungers. And that spring can be extremely difficult to find!

Small Hole Gage. When the telescope gage is too large, you can use a small hole gage to measure small holes or slots. Like the telescoping gage, the small hole gage, also shown in figure 5-15, is used with the micrometer or vernier caliper. When you check the measurement of a small hole gage, be sure to hold it perpendicular to the axis of the micrometer spindle or handle of the vernier caliper. You should also rotate it slightly from side to side as you bring the micrometer or caliper into contact with it. In this way you can be sure that you are measuring the largest diameter on the gage. Since the measuring surface of the gage is not a true circle, a slight misalignment in the micrometer or caliper will cause the reading to be erroneous.

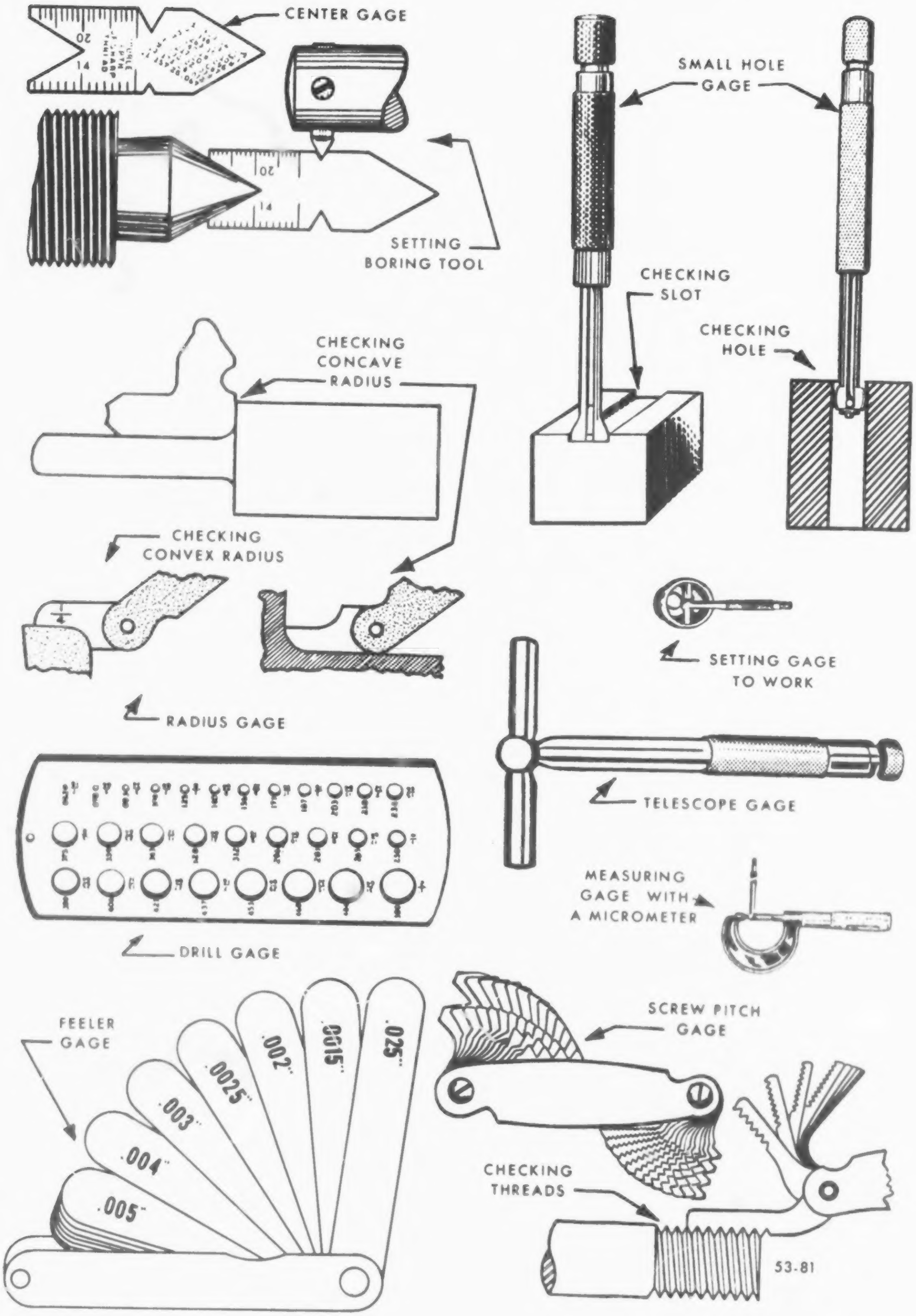

CENTER GAGE
SMALL HOLE GAGE
SETTING BORING TOOL
CHECKING SLOT
CHECKING HOLE
CHECKING CONCAVE RADIUS
CHECKING CONVEX RADIUS
RADIUS GAGE
SETTING GAGE TO WORK
TELESCOPE GAGE
DRILL GAGE
MEASURING GAGE WITH A MICROMETER
FEELER GAGE
.005"
.004"
.003"
.0025"
.002"
.0015"
.025"
SCREW PITCH GAGE
CHECKING THREADS
53-81

Figure 5-15. Various gages and their uses.

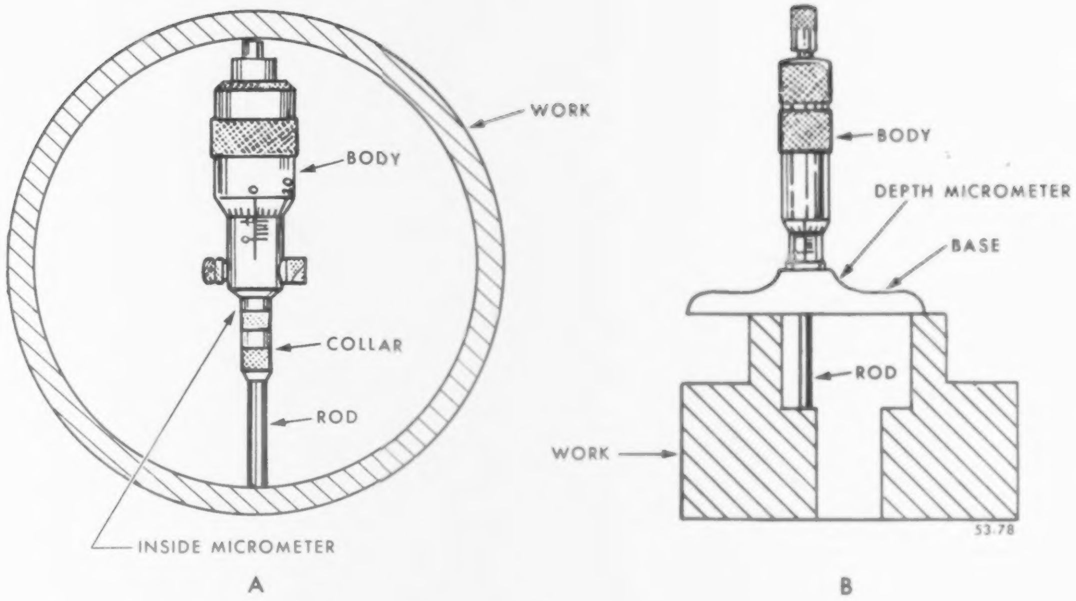


Figure 5-16. Inside and depth micrometers.

Exercises (034):

1. For what purpose are both the telescope gage and the small hole gage used?

2. What can happen if the head of a telescope gage becomes loose?

3. Why is it necessary to insure that a small hole gage is properly aligned while you are checking it with a micrometer?

035. Describe specific features of depth and inside micrometers, and explain various aspects regarding their use and care.

Depth micrometer. Depth micrometers are used to measure the depth of holes or the distance from one flat surface to another, as shown in part B in figure 5-16. The range of most depth micrometers is 1 inch. Extension rods allow the measurement of various distances: 1 to 2 inches, 2 to 3 inches, etc. The graduations on a depth micrometer are reversed from those on an outside micrometer. The 0.000 reading on an outside micrometer is obtained with all of the graduations on the barrel covered by the thimble; while on a depth micrometer, the graduations are all exposed for a 0.000 reading. The measurement obtained with a depth micrometer must include the lowest value of the extension rod being used. For example, if a reading of 0.567 is indicated when a 0- to 1-inch rod is being used, the measurement is actually 0.567 inch. If the same reading is obtained while using a 2- to 3-inch extension rod, the actual measurement is 2.567 inches.

When you use the depth micrometer, never hold or support it by the extension rod. If the rod is sprung or bent even slightly, you will be unable to obtain an accurate reading and installation and removal of the rod will be difficult. You should never slide the micrometer base along a surface with the extension rod in contact with another surface. The spindle should be backed off slightly between each measurement when you are taking a series of measurements. This action prevents damage to the extension rod and also helps insure that the base is resting flatly on the reference surface for each successive measurement.

Inside Micrometer. The inside micrometer is designed to measure internal dimensions. You use an inside micrometer, as shown in part A in figure 5-16, to measure the inside diameters of pipe, tubing, and holes and distances between surfaces. The measurements obtained may be just as precise as those obtained with an outside micrometer. However, the nomenclature differs slightly from that of other micrometers, and the range of an inside micrometer is usually only 0.500 inch. The body of the inside micrometer, often referred to as the head, is composed of the units that are called the barrel and the thimble of an outside micrometer.

Fully closed, most inside micrometers are 1.5 inches long. This length prohibits the measurement of dimensions smaller than 1.5 inches with most inside micrometers. You use extension rods of various lengths when measuring dimensions larger than 2 inches. The maximum measurement possible is governed by the length of the longest extension rod available. The longest single extension rod in most sets is 6 inches; however, some inside micrometers permit the mounting of extension rods on both ends of the body, increasing the maximum measurement that can be obtained.

Read inside micrometers in the same manner as you read outside micrometers except that the measurement must also include the length of the extension rod and the length of the body. For example, using a 3-inch extension rod and inside micrometer with a body length of 1.5 inches, you obtain a reading of 0.358. What is the diameter of the hole?

3.000—length of extension
1.500—length of body
0.358—reading obtained
4.858—actual measurement

One of the easiest ways to damage an inside micrometer is to extend it slightly more than the inside diameter of a cylindrical object and then force it past the diameter measurement when removing it. This situation can occur if the micrometer is not held at a right angle to the axis of the work when the final setting is made. The result is normally a bent extension rod.

Like the outside micrometers, the inside and depth micrometers should be protected from dust. Also, to prevent micrometer damage and erroneous readings, the extension rods for each should be wiped clean prior to installing them.

Exercises (035):

1. How are the graduations on a depth micrometer different from those on an outside micrometer?

2. What part of a depth micrometer is subject to damage merely by holding the micrometer incorrectly?

3. After measuring the inside diameter of an engine cylinder, the reading on the iside micrometer is 0.255. If a 2-inch extension rod was used, what was the actual diameter of the cylinder?

4. What can result from installing dirty extension rods in inside and depth micrometers?

036. Explain specific features of various vernier instruments.

Vernier Caliper. The vernier caliper, shown in figure 5-17, is quite similar to the caliper rule, except that it has a vernier scale. The vernier scale allows you to take measurements to within 0.001 inch. Vernier calipers have beams 6, 12, 24, 36, and 48 inches in length. Although slightly more bulky than the micrometer, one vernier can replace several sets of micrometers. For instance, a 12-inch vernier caliper has the same range of measurements as a set of 12 micrometers. Also, the vernier caliper is capable of making inside as well as outside measurements. The sliding jaw is thicker than the beam, allowing a vernier scale to be mounted on each side. One of the vernier scales is used for inside measurement, while the other is used for outside measurement. The vernier scale is a simple means of magnifying small differences in measurements so that they may be easily read on a linear scale. Although it would be possible to etch graduations of 0.001 inch on a steel scale, it would be almost impossible to read them. The addition of the vernier scale makes it a simple matter to read the 0.001-inch graduations. The main scale is divided into inches the same as a machinist's scale. The inch division is broken into 10 divisions of 0.100 inch. These divisions are further divided into four parts of 0.025 inch each. Thus, each graduation on the main scale equals 0.025 inch. The vernier scale (the lower sliding scale) divides the 0.025 inch main scale into 25 parts equal to 0.001 inch. When the index of the sliding scale (marked "0") is in alignment with a main scale graduation, you simply read the main scale graduations. When the index is not in alignment with a main scale graduation, you read the main scale division to the left of the index and add to that the number of marks to the right of the main scale division in alignment with the vernier scale.

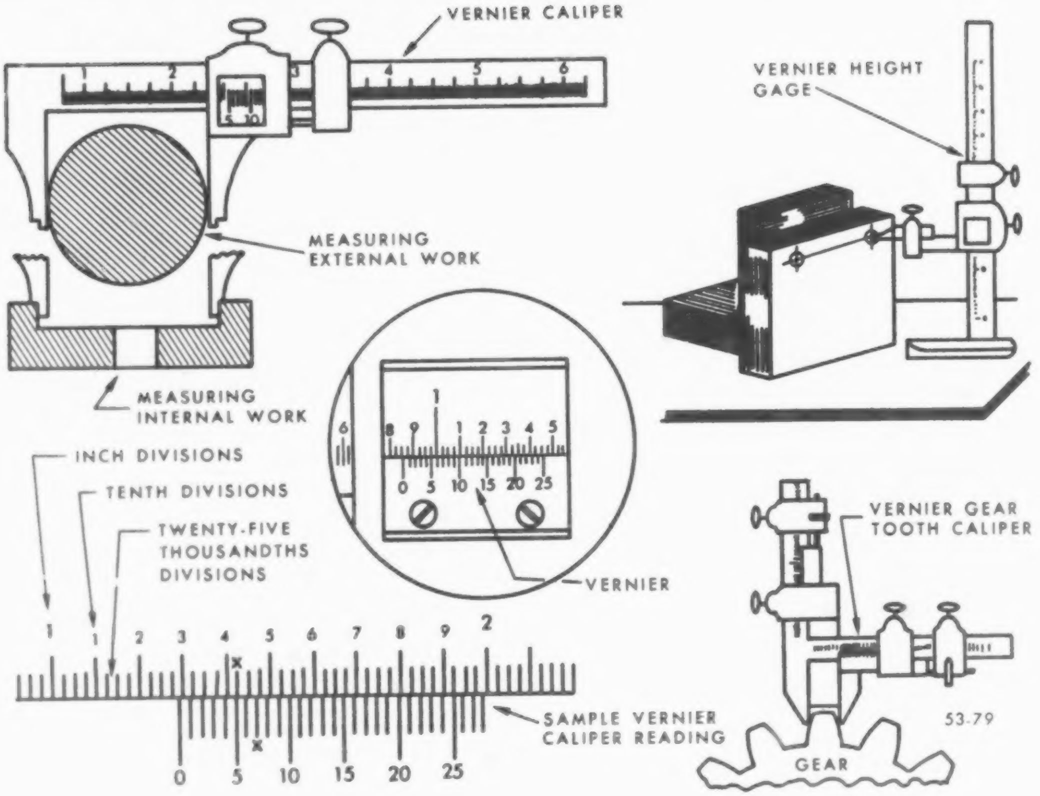

VERNIER CALIPER
VERNIER HEIGHT GAGE
MEASURING EXTERNAL WORK
MEASURING INTERNAL WORK
INCH DIVISIONS
TENTH DIVISIONS
TWENTY-FIVE THOUSANDTHS DIVISIONS
VERNIER
VERNIER GEAR TOOTH CALIPER
1 1 2 3 4 5 6 7 8 9 2
0 5 10 15 20 25
SAMPLE VERNIER CALIPER READING
GEAR
53-79

Figure 5-17. Varnier calipers and height gages.

Vernier Height Gage. The basic types of height gages fall into two categories: height gages for direct linear measurement and height gages for comparison measurement. You can use almost any height gage for both functions, depending upon the type of indicating system used. A variety of attachments is available to allow you to use the height gage with either system.

The vernier height gage may appear to be quite different from the vernier caliper. However, the basic principle is the same. When you place the vernier height gage on a surface plate, the surface plate becomes the equivalent to the fixed jaw. The sliding arm of the vernier height gage differs from the sliding jaw of the vernier caliper only in minor mechanical details. The sliding arm of the height gage is designed for mounting accessories for easier height measurement. Vernier height gages are normally produced in height capacities of 10, 28, and 24 inches. Thus, you can measure these heights with the respective models, even though the beam height is about 2 inches more. Like the vernier caliper, vernier height gages usually have 0.025-inch scale divisions and a vernier scale that permits you to read the scales to within 0.001-inch accuracy. The vertical beam or main scale of the vernier height gage is graduated in relation to the bottom of the base. The scale then reads the actual height of the gaging surface. The gaging surface is the top surface of the sliding arm. You normally clamp the scriber point on the gaging surface of the height gage as shown in figure 5-17. The scale of the height gage permits you to make direct readings to the gaging surface of the scriber point. Essentially, this is a caliper-type reading when used for measuring work. The scribing tip of the scriber point is also at the height of the scale readings. You can scribe lines accurately at the indicated heights. The scriber point can be mounted to the bottom side of the sliding arm. Then the height gage can be used in the same manner as an inside caliper. When you are using the height gage in this way, you must subtract the thickness of the arm from the reading. The minimum height at which you can set the sliding arm gaging surface above the bottom of the base is usually 1 inch. When measuring heights less than 1 inch, use the offset attachment. The offset attachment lowers the contact point of the height gage 1 inch, making the measurement of heights less than 1 inch possible.

Other Vernier Instruments. Figure 5-17 also shows a vernier gear tooth caliper. It is used to measure various gear teeth dimensions such as the cordal thickness (the thickness of the tooth at the pitch circle). The scales are read in the same manner as the vernier caliper.

Not shown in figure 5-17 is the vernier bevel protractor. It is used to measure and check angles with greater accuracy than the protractor in the combination set. The vernier bevel protractor accurately divides each degree into twelve 5-minute segments with a vernier scale. Therefore angles can be measured to within 5 minutes of their true dimensions.

Exercises (036):

1. Explain why a vernier caliper is more versatile than a micrometer.

2. On the vernier caliper and height gage, what part of an inch does each graduation on the vernier scale represent?

3. What attachment to the height gage allows you to measure heights less than 1 inch from the bottom of the base?

4. Which vernier tool is used to measure the thickness of a gear tooth at the pitch circle?

5. The vernier scale on a bevel protractor is divided into a number of segments, each representing how many minutes?

037. Describe procedures for using dial indicators.

Dial Indicators. A dial indicator, shown in figure 5-18, is a precision instrument that is used to determine the smoothness or concentricity of a surface. The linear movement of the spindle is amplified by a gear train and is translated into rotation of a pointer over a graduated dial so that a spindle movement of a thousandth of an inch or less can be read on the dial. The scale on the dial reads both to the right and left of zero and thus indicates when you have properly adjusted the instrument to the work. Part B in figure 5-18 shows a dial indicator set up for checking an arbor.

Dial indicators can be used to great advantage in combination with a surface plate and V-blocks for checking for curvature in a shaft. To do this, you place the part on two "V" blocks with about one-fourth inch of each end of the shaft resting on a "V" block. Move the indicating gage over the part and set the dial for a zero reading. Then you take three more readings (90° apart) around the shaft. Repeat this at several stations along the shaft in order to separate bent shaft conditions from other conditions.

When you use a dial indicator, check to see what the maximum recommended shaft or spindle movement is and don't exceed it. Forcing the shaft beyond its limits can severely damage the indicator. Also, never tap on a part when the indicator is in contact with it. Such tapping has almost the same effect as tapping on the indicator itself. Unfortunately, this is a fairly common mistake made by persons while they are attempting to align a part on a face plate in a lathe. After rotating the face plate and determining the amount of runout, they pick up the hammer and tap the work in the proper direction. The indicator should *always* be backed away from the work before tapping on the work.

Exercises (037):

1. When checking a shaft for curvature, how many readings should you take around the circumference of the shaft at any one position?

2. What should you check prior to using a dial indicator?

3. What happens to a dial indicator when it is in contact with work that is struck with a hammer?

5-3. Special Tools

There are several precision tools that you may have occasion to use that are of a more

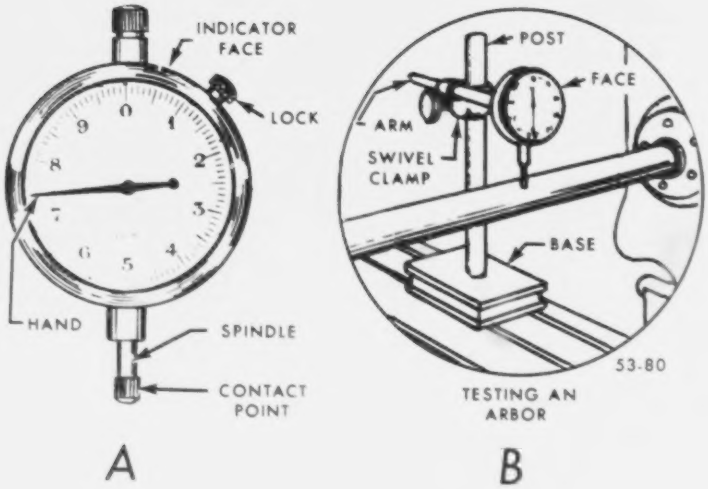


Figure 5-18. Dial indicator.

specialized nature than those that we have already discussed. In this section, we shall examine some of these special tools, such as surface plates, gage blocks, sine bars, and toolmaker's buttons. All of these tools must be treated with special care and respect if they are to retain their accuracy and usefulness.

038. Describe the surface plate and the bench plate and explain their use and care.

Surface Plate. You use a suface plate when a flat surface with a high degree of accuracy is required. Surface plates are made of close-grained cast iron, granite, or ceramic material. After being machined accurately, the surface is handscraped flat and smooth. Surface plates are available in various sizes ranging from several inches in width and length to 8 feet wide and 10 feet long. Ribs are cast into the underside of the plate to prevent warpage of the flat surface.

You use the surface plate for making accurate layouts, as well as for ordinary layout work. You use it in conjunction with precision measuring instruments to check the accuracy of gages and measuring instruments.

A good surface plate is an expensive piece of equipment. The cost of a particular surface plate depends upon the material from which it is made, its size, and its accuracy. You must give the surface plate proper care if it is to maintain its accuracy. The working surface must be kept clean and free of foreign matter. Do not drop any object on its surface. Do not hammer or pound on a surface plate or on any part resting on the surface plate. Keep the surface lightly oiled and covered to prevent damage when the plate is not in use.

Bench Plate. Bench plates are very much like surface plates except that they are not finished to such strict tolerances. Bench plates are normally made from cast iron and are produced in several sizes. An average-sized bench plate may be about 18 inches square and about 1½ inches thick.

You use the bench as a base upon which to work. You use the bench plate for ordinary layout work when great accuracy is not required. You can lay the work directly on the plate, clamp it to angle plates, or hold it on "V" blocks. Like the surface plate, the accuracy or usefulness of the bench plate will be impaired if it is hammered or pounded on.

Exercises (038):

1. How is the surface plate's smooth, flat finish produced?

2. List two uses of the surface plate other than layout work.

3. What should you do to protect the surface plate when it is not in use?

4. How does the bench plate differ from the surface plate?

5. What can happen to bench or surface plates if they are used as a base for center-punching various objects?

039. Describe and explain the use and care of precision gage blocks.

Precision Gage Blocks. A precision gage block is a piece of alloy steel that has been carefully prepared in length to represent a particular dimension. A standard length of measurement is engraved on each block. Precision gage blocks come in sets consisting of many blocks, each with a different dimension. In addition to each individual dimension, you can construct other dimensions with a set of blocks.

Gage block sets. Gage block sets usually consist of from 5 to 103 blocks of various lengths. Each set is supplied with a fitted hardwood case. The case keeps the gage blocks neatly arranged for easy selection, as well as protected from damage. Gage blocks are manufactured in various degrees of accuracy. The highest grade is grand master or grade AA. These blocks are manufactured to an accuracy of two millionths (0.000002) of an inch to an inch of length. Grade A blocks have an accuracy of six millionths of an inch in blocks of 1 inch and longer and two millionths of an inch accuracy for blocks under 1 inch. The blocks that you will most probably use are grade B. They are known as the working blocks. These are manufactured within a length tolerance of plus ten millionths (0.000010") and minus six millionths (0.000006") tolerance. Each block has its deviation from the nominal size engraved on the block.

Using gage blocks. When you use the gage blocks, it is necessary for you to select the combination of blocks to give you the dimension required. You simply select the proper blocks from the set that totals to the dimension that you require. Usually, you select from the larger blocks and add to the smaller ones to obtain the dimension, using as few blocks as you can. Once you have selected a stack of blocks, you must then properly stack them. Much of their precision depends upon the way that they are stacked. The correct method of joining them together is called "wringing."

Be sure that the gage blocks are absolutely clean of any foreign matter when they are in use. Also, be sure that your hands are clean and free of oil or dirt. Grease-soiled hands are rarely free of grit. Grit is harmful to gage blocks. Avoid touching the gage block gaging surfaces with the hands as much as possible. Moisture in the hands contains an acid that induces rust. Keep surfaces and parts clean where they come in contact with the gage block gaging surfaces.

You are now ready to wring the stack of blocks together. Bring the blocks lightly together in a circular motion, as shown in figure 5-19. You can thus detect the presence of nicks or dirt. If a nick or dirt is present, it will result in a slightly gritty feeling rather than a smooth action. Further wringing should

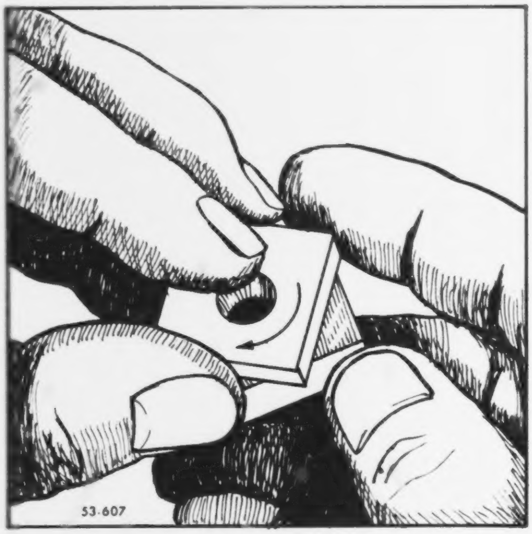


Figure 5-19. Wringing out gage blocks.

not be attempted until the condition is remedied. If the wringing produces a smooth action, slide the top block half way off the lower block. Apply a light pressure and follow by sliding the block into full contact under light pressure. In this position they are properly wrung together and ready for use. Properly wrung stacks of gage blocks will adhere to each other enough to defy the force of gravity.

Gage blocks have many uses in the machine shop. One of the primary uses is to check other gaging devices. You can use them as standards for checking the calibration of such instruments as a micrometer and vernier caliper and height gage. Also, you can use them as the standard for setting comparison instruments. You will use them, too, for setting up toolmaker's buttons and sine bars, which we shall cover in the next two discussions.

Exercises (039):

1. The gage blocks that you would most likely use in the shop are manufactured with what tolerance?

2. How can you determine the amount of size deviation in each gage block?

3. What is the purpose of wringing gage blocks together when you are using them?

4. Why shouldn't you touch the gaging surface of the blocks with your bare hands?

5. What condition is absolutely essential before gage blocks can be properly wrung together?

6. List the uses of gage blocks.

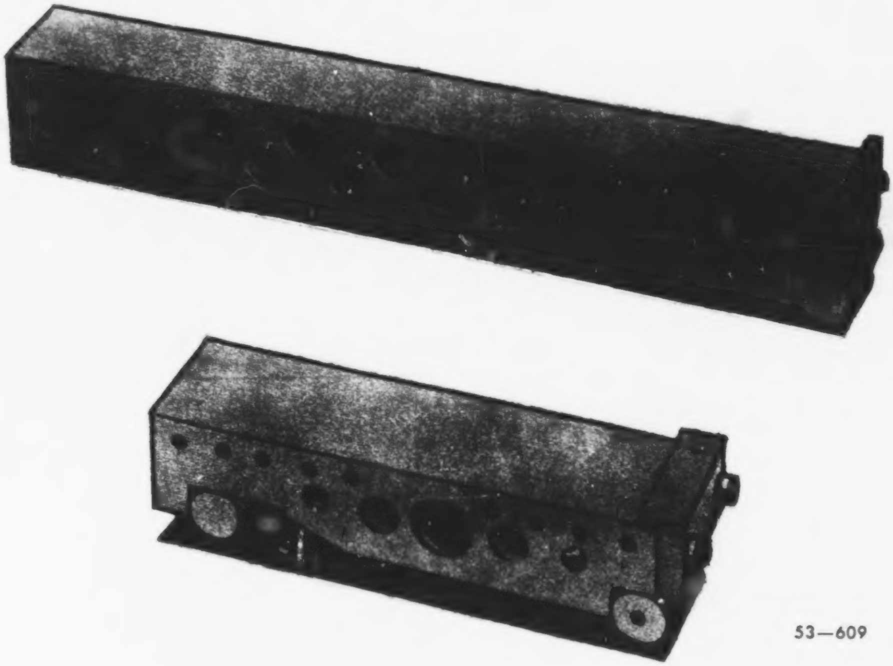


Figure 5-20. Sine bars.

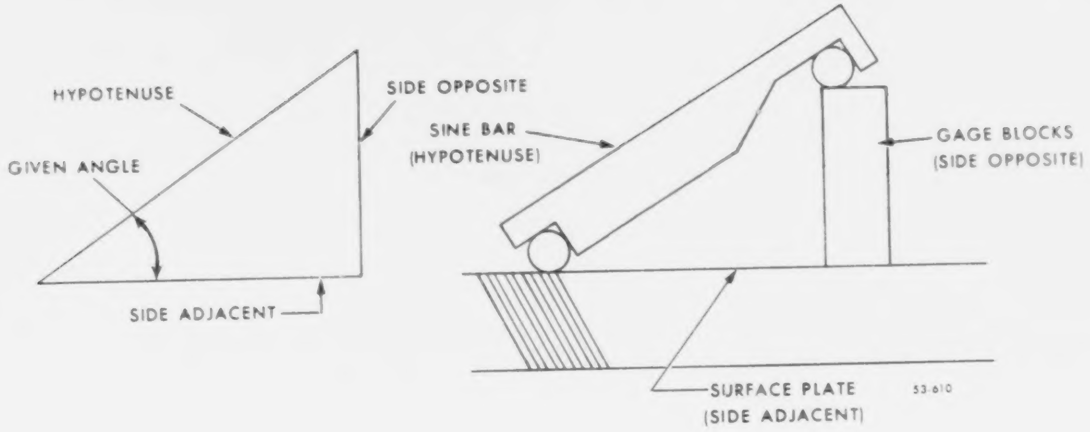


Figure 5-21. Setup of the sine bar.

040. Indicate specific procedures relating to the use and care of sine bars.

Sine Bars. A sine bar is a precisely machined tool steel bar that is used in conjunction with two steel cylinders. In the type shown in figure 5-20, the cylinders establish a precise distance of either 5 inches or 10 inches from the center of one to the center of the other, depending upon the model used. The bar itself has accurately machined parallel sides and the axes of the two cylinders are parallel to the adjacent sides of the bar within a close tolerance. Equally close tolerances control the cylinder roundness and freedom from taper. The slots or holes in the bar are provided for the convenient clamping of work pieces to the bar. Although the illustrated bars are typical, there is a wide variety of specialized shapes, widths, and thicknesses.

Sine bar setup. The sine bar itself is very easy to set up and use. You do need to have a basic knowledge of trigonometry to understand how it works. When a sine bar is set up, it always forms a right triangle. A right triangle is a triangle that has one 90° angle. The base of the triangle formed by the sine bar is the surface plate, as shown in figure 5-21. The side opposite is made up of the gage blocks that raise one end of the sine bar. The hypotenuse is always formed by the sine bar, as shown in figure 5-21. The height of the gage block setting may be found in two ways. The first method is to multiply the sine of the angle needed by the length of the sine bar. The sine of the angle may be found in any table of natural trigonometric functions. For example, if you had to set a 10-inch sine bar to check a 30° 5' angle on a part, you would first go to a table of natural trigonometric functions and find the sine of 30°5'. Then multiply by 10 inches: .50126 X 10 = 5.0126, which would be the height of the gage blocks. The second method is by using a table of sine bar constants. These tables give the height setting for any given angle (to the nearest minute) for a 5-inch sine bar. Tables are not normally available for 10-inch bars because it is just as easy to use the sine of the angle and move the decimal point one place to the right. Tables for the 5-inch sine bar can be found in machinist publications such as the *Machinery's Handbook.*

Sine bar care. Although sine bars have the appearance of being rugged, they should receive the same care as gage blocks. Because of the nature of their use in conjunction with other tools or parts that are heavy, they are subject to rough usage. Scratches, nicks, and burrs should be removed or repaired. They should be kept clean from abrasive dirt, sweat, and other corrosive agents. Regular inspection of the sine bar will locate such defects before they are able to affect its accuracy. When sine bars are stored for extended periods, all bare metal surfaces should be cleaned and then covered with a light film of oil. Placing a cover over the sine bar will further prevent accidental damage and discourage corrosion.

Exercises (040):

1. What part of a right triangle is represented by a sine bar?

2. What should the height of the gage blocks be to set an angle of 32°21' if a 10-inch sine bar is used and the sine of the angle is 0.53509? If a 5-inch sine bar is used?

3. How should a sine bar set be stored?

041. Determine the procedures for using toolmaker's buttons.

Figure 5-22. Toolmaker's buttons.

Toolmaker's Buttons. Toolmaker's buttons are hardened and ground cylindrical pieces of steel. The ends are ground flat or slightly concave. The buttons have a large hole through them to allow you to fasten them to the workpiece and to change the location of the button. Toolmaker's buttons are normally available in sets of four with set diameters of .300, .400, or .500 inch. Usually, buttons are 1/2-inch long with one button 5/8-inch long. Toolmaker's button sets, shown in figure 5-22, are furnished with the screws and hardware for fastening the buttons to the work and for proper storage.

You use toolmaker's buttons to locate holes with precision. You would make the layout with ordinary layout tools. After the centers of the holes are located, they are drilled and tapped to receive the toolmaker's button screws. The buttons are screwed lightly to the work.

At this point, you may be wondering why you should bother with the buttons since you already have the hole centers located. The problem is that even with the most careful layout and center-punching work, errors of two or three thousandths in center location are *very* hard to avoid. The toolmaker's buttons can help you correct these errors.

When you have two or more holes close together, use the long button for the hole that you want to drill first. This procedure will allow you to use the dial test indicator to center the work without interference from the other buttons. After you have the buttons accurately located, you then tighten them securely. When you require the buttons to be set with extreme accuracy, it is best to set them one button at a time.

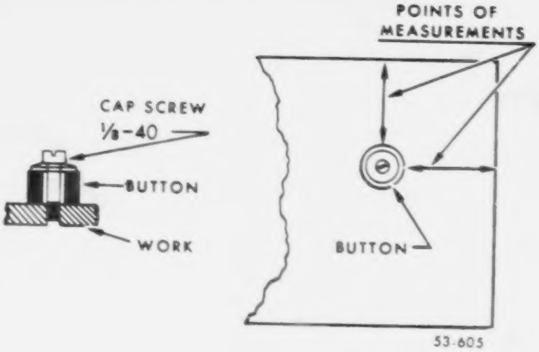


Figure 5-23. Toolmaker's buttons and their application.

Let's assume that you need to bore two accurately located holes from the end and edge of the work with accurate center distances. You must locate one button and then locate the other button relative to the first one. First you must insure that the first button is located the prescribed distance from the end and edge of the work. You can do this with the aid of a surface plate, angle plates, and gage blocks. Suppose the requirements are that the center of the hole be 1 inch from the edge of the part with its center 1½ inches from the end. Select the proper sizes of gage blocks to give these distances. The correct amount of gage blocks is the required distances minus one-half the diameter of the buttons. Align the button, as shown in figure 5-23. When the button is accurately located, tighten the screw to hold the button securely.

You may then locate the second button by using gage blocks. You would use the same stack that you used to locate the distance of the first button to locate the edge distance of the second button. Since the part requires accurate center distances between the holes, you locate the second button relative to the first. Suppose the center distance is 3.250 inches. You select the correct amount of gage blocks to fit between the buttons. Since the gage blocks are located between the buttons (buttons 1/2 inch in diameter), you subtract one-half the sum of the diameters of the buttons, as indicated in figure 5-24.

You may also use a micrometer to set the center distance between the buttons. You measure the distance across the buttons, and

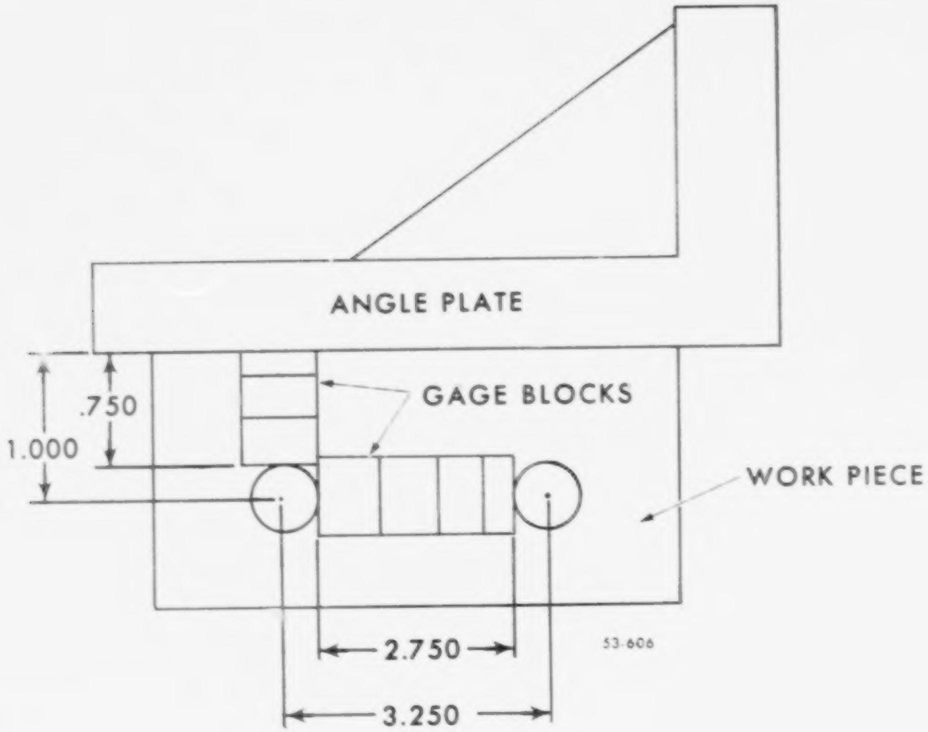


Figure 5-24. Setup for toolmaker's buttons.

you subtract one-half of the sum of the diameters of the buttons to the center distance to obtain the correct micrometer reading. The gage blocks may be used to check the edge distance of the second block. When you have the second button located, tighten the retaining screw securely.

You can use a dial test indicator to check the edge distance of straight line holes. After repeated checking of the locations of the buttons, check to insure that they are secure to the work. Make a final check of the button locations after the screws are tightened. You now have the holes accurately laid out with the toolmaker's buttons. The part is ready for the boring operation.

If the part is to be bored in a lathe, you mount the part on a face plate. You locate the part by using a dial test indicator on the buttons. When you have the button centered to within tolerances by lightly tapping the work, tighten the clamps securely. Recheck the reading after securing the work. You then remove the button and drill and bore the hole to specifications. Repeat the centering of the buttons for the remaining holes and bore them to specifications. If you perform these operations carefully, you will be able to drill and bore holes with very accurate locations.

Exercises (041):

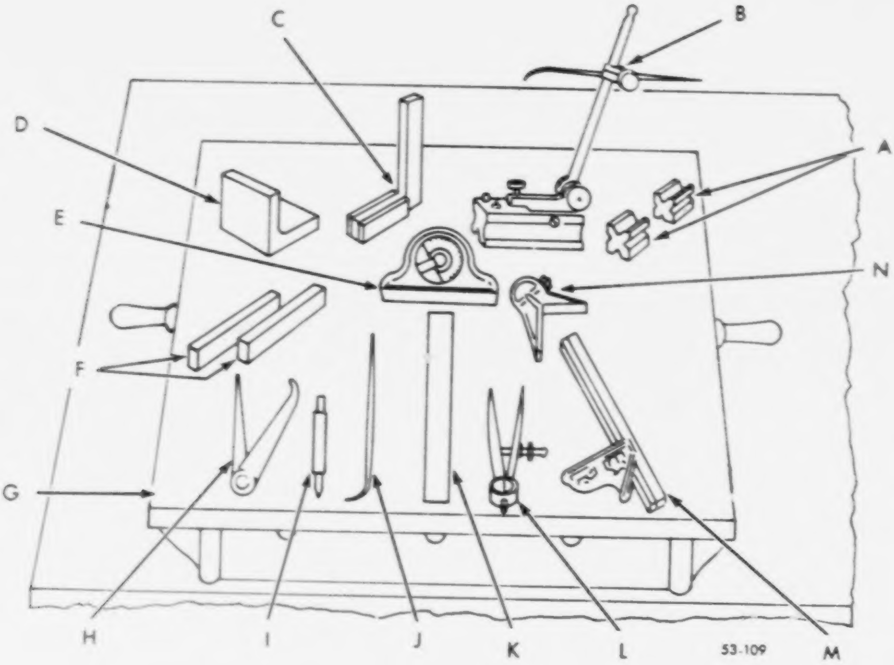
1. Why is one button in a set of toolmaker's buttons usually longer than the others?

2. If you have hole centers located by layout lines, why would you use toolmaker's buttons?

3. If you were required to locate two holes 2.375 inches apart and you were using 1/2-inch diameter buttons, what amount of gage blocks would be required between the buttons?

4. If you had to use an outside micrometer instead of gage blocks to check the button locations indicated in exercise 3, what would the micrometer reading be when the buttons were set properly?

5. After you have accurately located the buttons on the work, how could you-



A. V-blocks
B. Surface gage
C. Toolmaker's square
D. Angle plate
E. Protractor head
F. Parallels
G. Surface plate
H. Hermaphrodite caliper
I. Center punch
J. Scribe
K. Rule
L. Dividers
M. Square head and blade
N. Center head

Figure 5-25. Common layout tools.

insure that a particular hole will be accurately aligned on a face plate of a lathe for a boring operation?

5-4. Layout Work

You will be required at times to lay out work prior to machining it. Laying out the work is planning the work on the surface of the material. It is the scribing (marking) of lines that indicate the boundaries, centers, and other locations on the object so that you are able to machine it to the desired size and shape. The care with which you do layout will determine the accuracy of the finished work.

042. Explain various layout procedures and indicate specific tools and equipment used in the process.

Layout Compound. To lay out work, you scribe lines on a layout compound that has been applied to the surface of the work. A commercial layout blue dye is most often used. This is a liquid that dries rapidly, leaving a glare-resistant dark blue film on the work. Lines scribed through this film show up distinctly. Since the fluid evaporates rapidly, you should keep the container tightly closed when you are not using it. Apply a thin coating because the compound tends to flake or produce ragged lines when it is applied too heavily. Common chalk is often used to lay our rough finished surfaces. Regardless of the type of compound that you use, keep the surface clean and free of oil, and remove all burrs with a file or oilstone to prevent inaccurate measurements and possible injury.

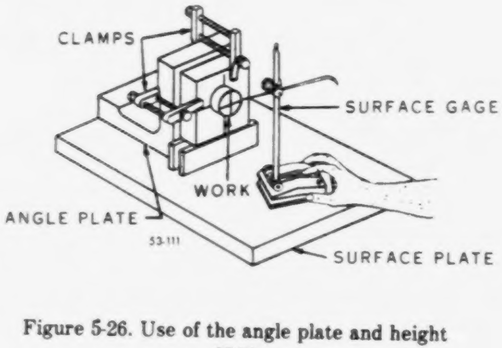


Figure 5-26. Use of the angle plate and height gage.

Layout Tools and Procedures. No matter what type of layout you do or what the object looks like, you will have to use layout tools. The shape of the object and the accuracy required will determine which tools to select. By knowing what the various tools are and what they are used for, you will be able to select the proper tools for laying out any given object. Figure 5-25 shows some common layout tools, some of which we shall be discussing.

Parallels. During a layout operation, parallels, V-blocks and angle plates are used mostly to support work in some particular position. Parallels are used when projections on the work prevent your setting it directly on the surface plate. They are also used when it is desirable to raise itens above the surface and still maintain parallelism. You should check parallels carefully for nicks and burrs before using them in layout work. Since they are also used extensively to support work for machining operations, they tend to become nicked and scratched. Nicks and scratches may keep them from resting flat on the surface plate and will, in turn, prevent you from producing accurate layout work. Any high metal on parallels due to minor nicks and scratches should be removed with a fine grained abrasive stone. Also, you shouldn't take the specified size of a parallel to be its exact true size. Older parallels may have been reground to restore the finish, making them undersize. Although the new size should be stamped on the end, such marking seldom gets done, so take an extra minute and check the size with a micrometer or vernier caliper.

V-blocks. V-blocks are used in layout work to support and secure round stock. They usually have clamps to keep the work stationary. You should use these clamps whenever possible. It will take a few extra seconds to put them on, but it is better than getting halfway through a job like the layout of several kayseats in line on a shaft and then finding out that the shaft has turned slightly during the process.

Angle plates. Angle plates have surfaces accurately machined at right angles to each other. They can be used to hold work at a right angle to the surface plate, to secure irregularly shaped work, or to secure work in a particular position. Like the V-blocks, it is best if you can clamp work to the angle plate during a layout operation. A C-clamp or parallel clamp is normally used for this purpose, as shown in figure 5-26.

Surface gage. The surface gage is used for scribing horizontal layout lines. It can be set at almost any angle to facilitate scribing lines on irregularly shaped work. Set the scriber point of the surface gage to the desired height on the blade of the combination set, using the square head to hold it in the vertical position. The thumbscrew near the back of the gage is used to obtain fine movement of the point for accurate settings; however, precision measurements should be layed out with the vernier height gage. Scribe only light lines with the surface gage since it does not take too much pressure to move a particular setting of the scriber even though you secure it with the friction clamp. Also, heavy lines cause excessive wear of the scriber point. This is true of the hand scriber as well as the one in the surface gage. When you scribe a line with either of them, don't go back and forth over the line. Doing so makes the line too wide for accurate layout.

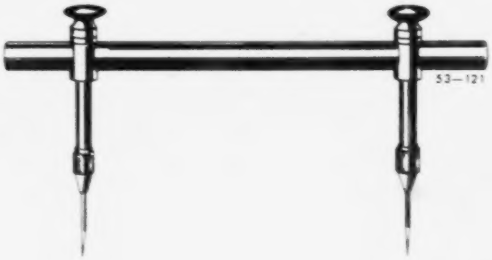


Figure 5-27. Trammel points.

Trammel points. We discussed dividers previously in this chapter, but we did not mention what to do if you need to scribe a circle or arc bigger than the reach of the largest available dividers. In this case, you could use a set of trammel points, shown in figure 5-27. Simple forms of this tool may easily be manufactured. The points must be able to slide along a suitable rod and have some kind of lockscrew on them. You use them in the same way as dividers.

Hermaphrodite caliper. Figure 5-28 shows some of the ways the hermaphrodite caliper is used. It can be used to locate the center of a boss or other round projection. To do this, set the caliper to a rough estimate of half the diameter of the boss and then scribe four arcs spaced approximately 90° apart. A small square will be formed around the true center. This method is not recommended when great accuracy is required.

Vernier height gage. The vernier height gage is used in layout work when very accurate dimensions are required. When you work with such dimensions, you should follow a few simple rules to help maintain the

a. First, clean all the dust and grit from the surface plate, the height gage, and the part on which you will work.

b. If you are making a new part, you should machine a blank with smooth, square surfaces from which you can make accurate measurements with the vernier height gage.

c. You should make all the measurements from no more than two adjacent sides if possible. Most blueprints are drawn in this manner, so it is fairly easy to determine which two surfaces to use. The reason for measuring this way is to prevent any error that might be present in the overall dimension of a blank from being transferred to the positioning of holes, slots, grooves, etc., within the part.

d. Normally, it is best to lay out only one surface at a time. The reason for this method is that when you perform the required machining operations for one surface, the layout lines on the other surfaces will usually get rubbed out or scratched over, making it necessary to rework them.

Exercises (042):

1. Why shouldn't layout compound be applied in heavy coats?

2. Why are parallels apt to have nicks and scratches that must be smoothed out before they can be used in layout work?

3. For what reason should you check the size of a parallel with a micrometer even though the size is stamped on the end of the parallel?

4. What is the purpose of V-blocks?

5. How can layout work be secured to an angle plate?

6. Explain why you should *not* try to scribe deep, heavy lines with the surface gage.

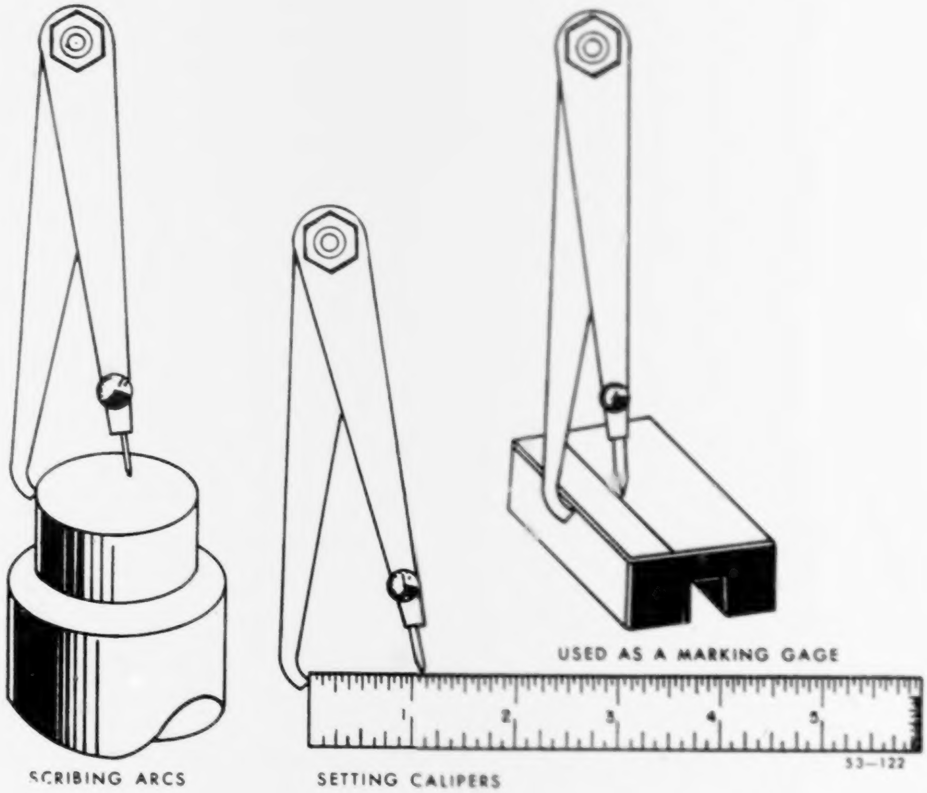


Figure 5-28 Using the hermaphrodite caliper.

7. What tool would you most likely use to scribe a circle having a 26-inch diameter?

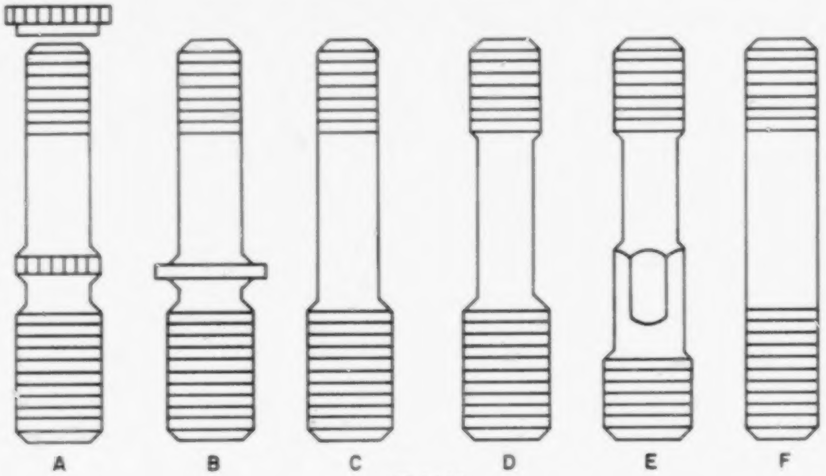
8. Before beginning work on a precision layout job, what should you do first to insure the greatest accuracy?

9. When laying out a premachined blank, why should you do as much of the measuring as possible from only two reference surfaces?

Studs, Plugs, Screws, and Inserts

ONE OF THE MOST time-consuming jobs that you will have to contend with as a machinist is removing broken or damaged studs, plugs, screws, and inserts. Normally, the number of jobs of this type that you are confronted with is in proportion to the extent of the mission requirements of the base or unit. In other words, a large base with moderate mission requirements will normally produce fewer damaged hardware jobs than a small base that has a heavy mission requirement. This is not to say that the mechanics and other technicians are not competent; it is just that haste and tension (both conditions always accompany increased work loads) cause people to take shortcuts that can easily lead to a broken screw, stud, bolt, etc.; and when that happens, you, the machinist, get called on to save the day! You must learn to work under pressure without losing your ability to think a problem through clearly and arrive at a logical and timely conclusion about the course of action to take. As you gain experience, you will find that tackling a job based on a hurried look at the situation can lead to twice the work as well as unnecessary damage to the equipment.

Unfortunately, there are no hard and fast rules to govern each situation that you will encounter. This is one area of your job that must be learned by drawing on the experience of others and by the experience that you will gain through your own actions. In this chapter, we shall try to give you some ideas that have proven successful in certain situations. We shall discuss removal and replacement techniques for studs, spark plugs, screws, and inserts. Also, we shall discuss some tools that you can make to help you in your job. Remember, as you read, that even though a particular technique may work perfectly in one instance, it may just as quickly fail in another. And you can decide on the best technique *only* after careful consideration of the entire job at hand.



A. Lock-ring stepped stud
B. Flanged stepped stud
C. Stepped stud
D. Necked stepped stud
E. Wrench pad necked stepped stud
F. Straight stud

Figure 6-1. Types of studs.

6-1. Studs, Plugs, and Screws

In this section, we shall discuss several types of studs and some techniques for removing and replacing them as well as screws and plugs. We shall also examine some helpful tools that can be fabricated in the machine shop. The techniques and methods given here are, by no means, the only ones that you should try. As you gain experience, you will undoubtedly develop some new techniques that work best for you. Whatever technique you use, you should strive to choose the one that will provide you with maximum safety and still get the job done.

043. Explain how some of the common types of studs are used.

Studs. The vast number of different types of aircraft and pieces of equipment in the Air Force inventory requires the use of a large variety of studs that vary in size, type, and shape. Figure 6-1 shows a representation of some of the more common types of studs. Studs are generally made with fine threads on one end and coarse threads on the opposite end, which is the end that fits into the parent part. Coarse threads are used because they are deeper and stronger.

Many studs are held in place only by the friction of the threads against the parent metal. On studs of this type (D and F in fig. 6-1), the fit or allowance between the stud and parent threads is critical. The stud must attain a certain torque value by the time it has reached the proper depth and yet must not exceed the maximum specified torque value. In cases where this type must be replaced, another stud of the same size will usually be too loose to be properly torqued. Therefore, oversize studs have been developed. On an oversize stud, the pitch diameter of the threads on the end of the stud that fits into the parent metal is increased, usually in 0.003 increments. Oversize studs have identification marks on the end that specify the amount over the normal pitch diameter. Figure 6-2 shows some of the typical oversize markings. Oversize studs are advantageous in that they allow the same parent metal threads to be used instead of drilling and tapping for the next size thread.

In figure 6-1, A, B, C, and E depict types of studs that can be locked into place by various special ways along with the friction created between them and the parent threads. Various stepped studs (C and E) are sometimes locked by inserting a small pin beside the stud in such a way that its diameter cuts into the threads of both the stud and the parent metal.

A flanged stud (B in fig. 6-1) is sometimes locked by a pin that is inserted through the flange. The pin normally does not cut into the threads, but it can be located entirely within

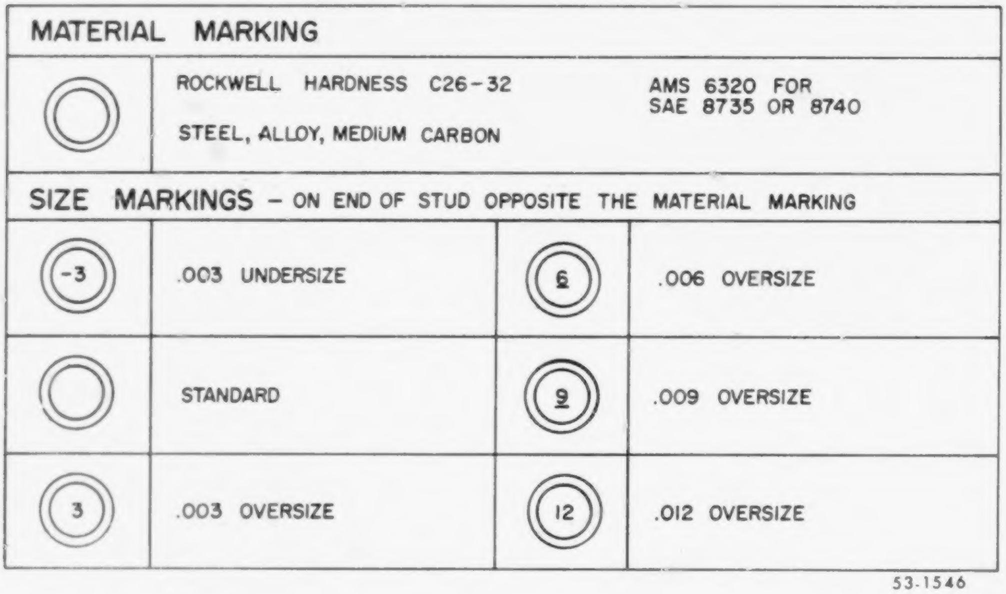
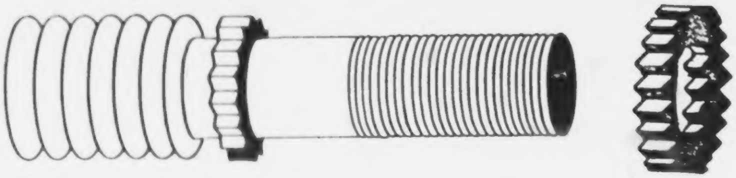


Figure 6-2. Identification markings on studs.



53-1545

Figure 6-3. Lock-ring threaded stud.

the flange or it may only extend a distance of half the pin diameter into the edge of the stud flange.

A lockring stud (A in fig. 6-1) is prevented from turning by a serrated ring. The flange on the stud has serrations that match those on the inside of the ring, as shown in figure 6-3. The stud is inserted into a specially prepared threaded seat until the top surface of the flange is flush with the surface of the parent metal. Then the ring is aligned with serrations on the flange and tapped down flush with the flange and surrounding metal. As it is tapped down, the serrations on the outside of the ring cut into the surrounding parent metal and prevent any circular movement of the stud.

The fact that there are so many different types and styles of studs means that it is imperative that you check the applicable technical order before you try to remove or replace one. The more that you know about a job before you start it, the easier it is to determine the best course of action.

Exercises (043):

1. Why are coarse threads used on one end of most studs?

2. Even though the parent threads may be worn, how can you attain specified torque values with a new stud?

3. How are stepped studs prevented from turning in the parent threads other than by friction between the two?

4. Explain how the lockring stud is prevented from turning after installation.

044. Explain various procedures in using methods of stud removal that do not require drilling the damaged stud.

In instances where a bolt is threaded directly into the parent metal instead of using a nut, the bolt is treated in much the same way as studs where removal techniques are concerned. Therefore, the methods described here for studs can be applied to bolts also.

Simple Stud Removal Methods. One of your biggest concerns when you are removing broken or damaged studs should be to protect the parent threads. The stud is much less expensive to replace than the part that it is screwed into, and many times, if the parent threads are destroyed, the whole part must be replaced. There are several things that you could try that do not involve a threat to the parent threads. These methods certainly will not work in all cases, but it takes very little time to try one or two of them, and if they should work, you will have saved yourself a great amount of time and effort. No matter what method you use, you can usually expedite the removal of a stud by applying penetrating oil to the stud and the parent part. The oil helps break up any corrosion between the threads. You must be careful, however, to keep the penetrating fluid from soaking electrical wiring, as oil will damage the insulation. Also, because some fluids should *not* be used on aluminum or its alloys, be sure to *check the label* on the container before you use a fluid on the part.

Scribe. A common hand scriber is sometimes all that is required to remove a broken or damaged stud. (This is especially true in the case of a bolt. Normally, when a bolt breaks because of vibration or shearing action, the threads that remain in the parent part are not too tight, since the pressure on them has been relieved.) When a stud breaks off flush with or below the surface of the parent part, you cannot grip it to turn it out. In these instances, the broken stud can sometimes be removed by hooking the point of the scribe on the top surface of the broken stud and rotating it out of the parent threads. Be careful not to apply too much pressure on the scribe or its point will break off. If the stud or bolt does not come out with light pressure, then another method should be tried.

Punch. If a stud has broken off flush with (or slightly below) the surface of the parent metal, removal can be accomplished in many cases with a punch and hammer. A center punch works well for this process because the included angle (90°) is steep enough to prevent the point from breaking and to prevent the punch from digging too deeply into the stud. When you use this method, seat the punch near the edge of the stud and then angle the punch in such a way to cause the stud to rotate. Be careful not to tap too hard; heavy blows might cause the stud to mushroom and make drilling necessary.

File and wrench. Sometimes a stud will break off in such a way that a portion will be above the surface of the parent metal. When this happens, a file and wrench will often be all that you need for removal. You simply file two flats opposite each other on the sides of the stud and then use the wrench to rotate the stud out. This method is especially useful when the stud is located in a position that prevents the use of a drill and extractor (we shall discuss these tools later).

Self-locking pliers. If properly used and cared for, the self-locking pliers (commonly called vise-grips, which is a trade name) can be one of your most useful tools. One of the first things to do in using this method is to check the pliers themselves. Lock the jaws together and check to see that the ends of jaws are even. If one overlaps the other, you should grind them off evenly. You can then clamp the pliers onto a stud even though only a small portion of the stud extends above the surrounding surface. (By locking the nose of the pliers onto the stud in such a way that the axis of the jaws is parallel to the axis of the stud, you can rotate the stud out. You don't have the greatest leverage this way, but the pliers will not slip off the stud nearly so quickly as they will if you attempt to lock the side of the jaws onto the stud.)

There is another removal method that does not involve drilling but does involve some special tools. We shall discuss this method next.

Exercises (044):

1. What should be your biggest concern (other than safety) when removing broken or damaged studs?
2. What precautions must you take when using penetrating fluid?
3. What must you be careful of when using a scribe to remove a stud?
4. When using a hammer and punch, what usually results from hitting the punch too hard?
5. Under what circumstances is the file and wrench method most advantageous?
6. Explain how to prepare self-locking pliers for their most advantageous use in stud removal.

045. State the advantages of locally produced stud removal tools over commercial kits and explain the procedures for making and using these tools.

Stud Removal Tools. There are several types of commercial stud insertion and removal kits available through supply. However, they generally are quite expensive. Also, in most

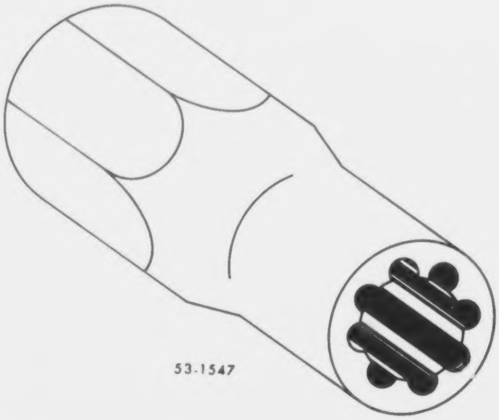


Figure 6-4. Locally produced stud remover.

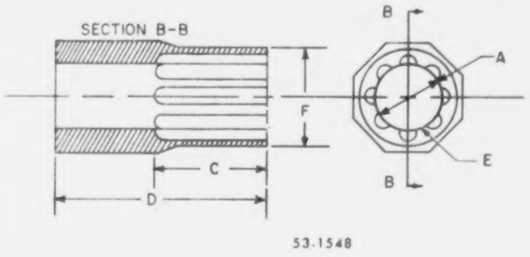


Figure 6-5. Print for locally produced stud remover.

cases, if a single part of the kit is damaged, an entire kit must be purchased to get the replacement part. Therefore, we offer a simple, economical, and effective substitute. Figure 6-4 shows a stud remover tool made from a piece of hex stock. This tool, as well as the commercial kits, can be used only when the damaged stud extends above the surface of the parent part, but this one has several advantages over the commercial tools: (1) it is smaller than the average commercial tool; (2) it can be used effectively on studs that extend only 1/16 inch above the parent surface, whereas the commercial tools normally require more grip length; (3) it is not easily damaged; and (4) it can be replaced very economically.

When you make a stud remover of this type, it is best to make a set. You should determine the sizes of the studs that you must remove most often, and make a remover for each of those sizes. Figure 6-5 shows a plan for a typical tool. A good grade of hardenable steel (SAE 4340, etc.) hex stock should be used. Diameter A is drilled through the tool and should be equal to the minor diameter of the stud thread. The length of the splines (dimension C) should be ½ to ¾ inch but then can be extended through the tool. They are produced in the following manner. After the minor diameter hole has been drilled through, make a steel plug and press it into the hole flush with the end that is to be splined. Then mount the tool in an indexing head and drill a series of equally spaced holes on the circle formed by the plug and the tool. Then simply remove the plug; the spaces between the holes are the splines.

The diameter of the spline holes must be at least twice the single thread depth on the stud but preferably a little larger. The width of the spline face (E in fig. 6-5) should be from 1/32 inch for smaller studs and 1/16 inch for larger ones. You can compute the number of holes that will be required to produce a particular spline face width in the following manner. Suppose you want to produce a tool for removing a ½-20 stud. Since this is a fairly large stud, a spline face width of 1/16 inch would be best. To determine the number and diameter of the spline holes, first choose a drill size slightly larger than the double depth of the stud thread. The double depth of thread for 20 threads per inch is approximately 0.062 inch. A 7/64 (0.109-inch) drill is a good choice for the drill size, since it is close to the double thread depth and still big enough to provide clearance for the stud threads between the splines when the tool is used. Now add the drill size to the required spline face width.

$$0.109 + 0.262 = 0.171$$

Next, divide the circumference of the center hole (fig. 6-5, A) by the previously obtained sum. The center hole for a ½ - 20 stud remover would be 0.437 inch. The formula for computing circumference is $C = \pi d$. Thus, the following computations apply to the situation:

$$C = 3.1416 \text{ x } 0.437 = 1.373 \text{ inch}$$
$$1.373 + 0.171 = 8 \text{ (rounded off to nearest whole number)}$$

Therefore, eight 7/64-inch diameter holes will produce a spline face width of approximately 1/16 inch.

The overall length (D in fig. 6-5) need not be over 1¼ inch. The short length allows the tool to be used in tight places. Turning the hex off the splined end (F in fig. 6-5) will also help. Before the tool is hardened, the size of the stud on which it is to be used should be marked on the side of the tool. Finally, have the tool hardened to approximately Rockwell C-43 or 45.

To use the completed tool, you simply center it on top of the stud and then use a hammer to drive it down over the stud. As you drive the tool down onto the stud, the splines cut into the threads and lock the tool onto the stud. A wrench can then be used on the tool to remove the stud.

Exercises (045):

1. What advantages does the locally produced stud removal tool have over most commercial kits?

2. How are the splines formed in the locally produced stud removal tool?

3. How many spline holes should be drilled in a removal tool for a 3/8 - 24 stud thread when the minor diameter of the thread is 0.323 inch, a 1/16 (0.062) drill bit is used, and a 3/64-inch spline face width (approximate 0.047 inch) is desired?

4. Explain the function of the splines when the removal tool is used.

046. Explain the procedures for making and using stud extractors.

Stud Extractors. You can use extractors, such as the Ezy-Out shown in figure 6-6, to advantage to remove studs, plugs, screws or inserts without damaging the parent metal. An Ezy-Out has a square tapered body with a left-hand twist, giving it the appearance of a left-hand thread. When the Ezy-Out is inserted in the drilled hole in the stud, it tends to screw in and lock in position.

NOTE: A hole drilled in a stud should be as close to the center of the stud as possible.

You can normally remove a stud with an Ezy-Out by using the proper amount of pressure to turn it out. However, the Ezy-Out will not always remove the stud, and it is easily broken by too much twisting pressure. For ordinary conditions, the makers of Ezy-Out recommend certain drill sizes such as the sizes shown in figure 6-7. Unusual conditions may require the use of larger drill sizes, depending upon the length of the broken part or its depth in the parent part. If commercial extractors are not available, you can make a good stud extractor by grinding a high-speed lathe tool with a square tapered end, as shown in figure 6-8. Drive the square tapered end lightly into the hole drilled in the stud. The square taper cuts into the wall of the stud, giving the tool grooves to hold in when you twist it with a wrench. You should turn the Ezy-Out or the ground tool with even pressure. The best way to do this is by using either a tap wrench or two wrenches placed opposite one another on the extractor shank. Apply pressure equally to both. Equal pressure is especially important in the initial loosening of the stud. Usually, once a stud is loosened in this manner, it will screw out of the hole without further difficulty. But if the stud is corroded too badly, the extractor will slip out or break when you apply the twisting force.

NOTE: Before using either a commercial

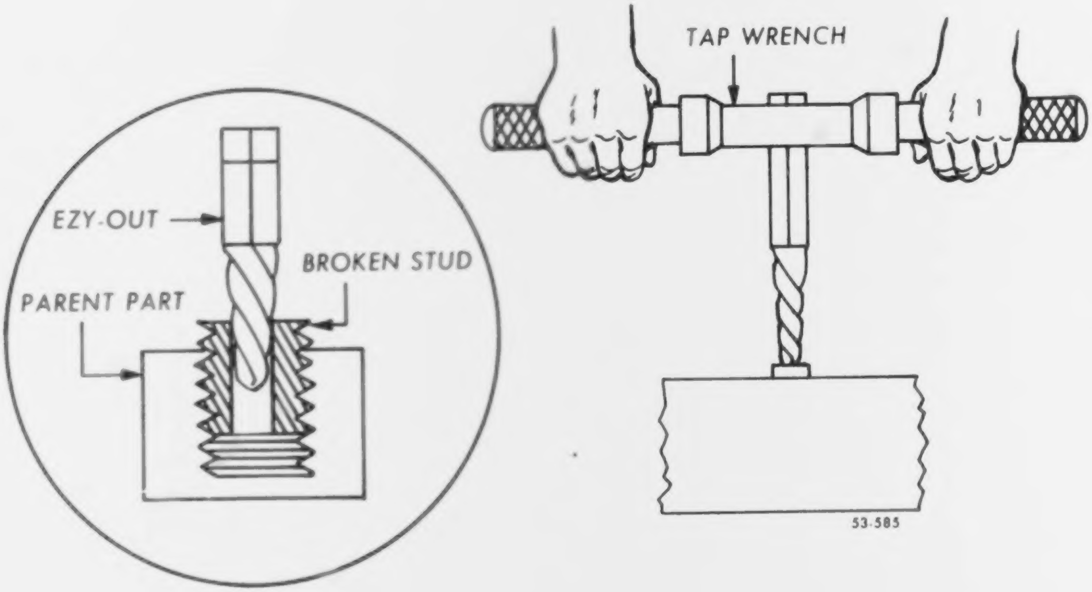


Figure 6-6. Commercial-type Ezy-Out extractor.

EXTRACTOR NUMBER	DIAMETER AT SMALL END (INCHES)	DIAMETER AT LARGE END (INCHES)	LENGTH OF FLUTES (INCHES)	LENGTH OVERALL (INCHES)	SIZE DRILL TO USE (INCHES)
1	0.054	0.117	1/2	2	5/64
2	0.080	0.174	3/4	2 3/8	7/64
3	1/8	1/4	1	2 11/16	5/32
4	3/16	21/64	1 1/8	2 7/8	1/4
5	1/4	7/16	1 1/2	3 3/8	17/64
6	3/8	19/32	1 3/4	3 3/4	13/32
7	1/2	3/4	2	4 1/8	17/32
8	3/4	1	2	4 3/8	13/16
9	1	1 9/32	2 1/4	4 5/8	1 1/16
10	1 1/4	1 9/16	2 1/2	5	1 5/16
11	1 1/2	1 7/8	3	5 5/8	1 9/16
12	1 7/8	2 5/16	3 1/2	3 1/4	1 15/16

53-586

Figure 6-7. Drill sizes for Ezy-Out screw extractors.

Ezy-Out or a ground tool to remove a broken stud, you should drill the stud through its *entire length*. Then, if the Ezy-Out or ground tool should break off inside the stud while you are attempting to remove it, the broken off piece can be driven down into the space between the end of the stud and the bottom of the hole. The stud can then be drilled out without damaging the drill or the hardened piece of the extractor.

When you make an extractor from a tool bit, be careful not to allow the tool bit to overheat during the grinding. If it becomes hot enough to darken the metal, the chances are increased that it will break during stud removal.

A point to remember when inserting an extractor into a stud is to tap it in only sufficiently to seat it tightly. If you drive it in hard enough to break the wall of the stud, removal becomes much more difficult. Also, the danger of damaging the parent threads is greatly increased.

Exercises (046):

1. What is an important rule concerning the location of an extractor hole in a stud?

2. What is the size of drill recommended for drilling a hole for a number 4 Ezy-Out extractor?

3. If a tap wrench is not available, how should an extractor be turned initially?

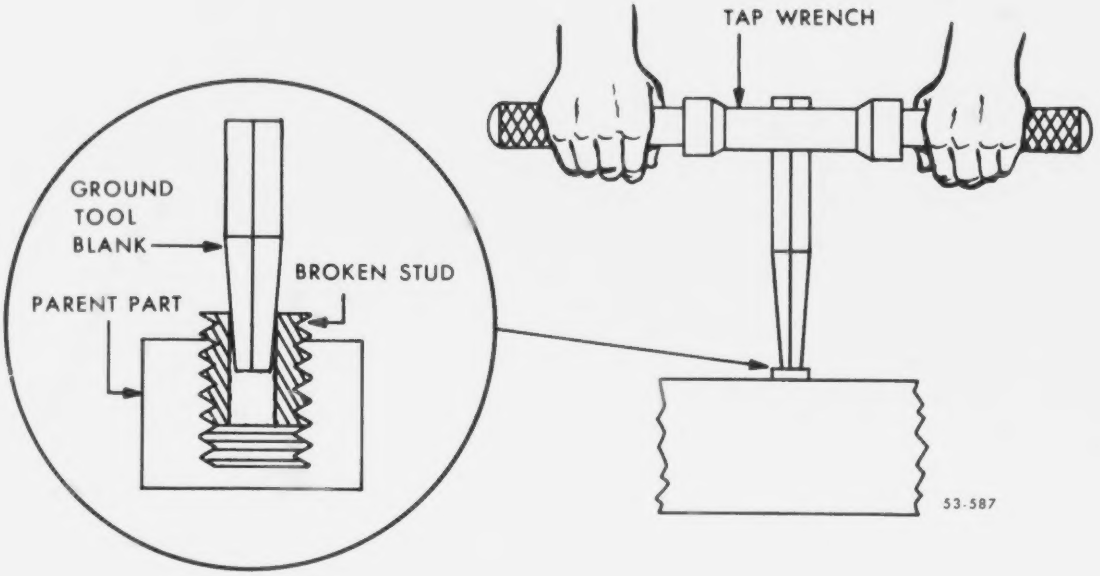


Figure 6-8. Ground tool type of extractor.

4. Why shouldn't an extractor made from a tool bit be allowed to overheat during grinding?

5. What can result from driving an extractor too deep into a stud?

047. Explain the procedures for removing broken or damaged studs by drilling, indicating some of the problems involved.

Removing Studs by Drilling. Broken studs may be removed by drilling out the portion left in the parent part, as shown in figure 6-9. There are several methods of drilling out broken studs. Probably the most accurate method of drilling is to use a drill jig. However, due to close working quarters, you will sometimes have to drill without a jig. Usually, you should try to spot punch the center of the broken stud, as shown in figure 6-10, and the drill for an extractor. The accuracy of the drilled hole will depend entirely upon your skill, and if the extractor fails, you will have to drill the stud completely out. The object of drilling is to drill out the exact center of the stud and not touch the threads in the parent part. If you leave a thin enough wall, you can sometimes remove the remainder of the stud with the point of a scribe or a similar sharp-pointed tool.

The ideal place to remove a stud by drilling

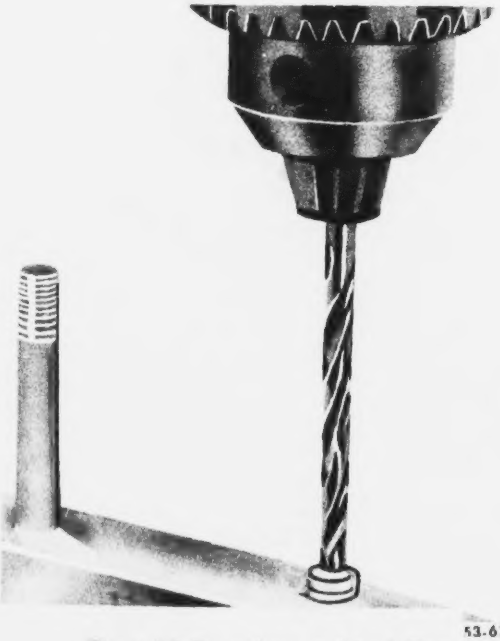


Figure 6-9. Removing a stud by drilling.

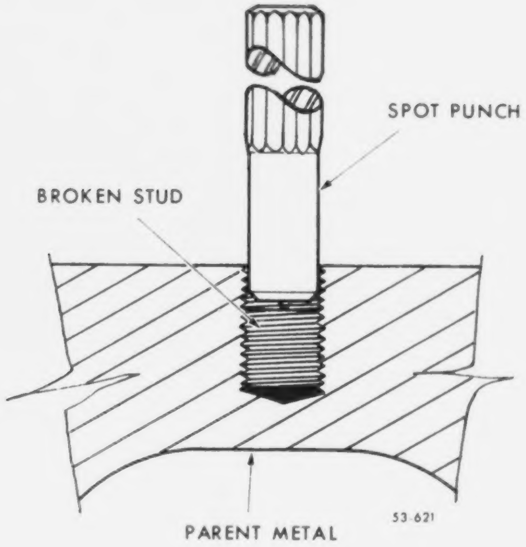


Figure 6-10. Spot punching a broken stud.

is in the shop; however, most of the time it must be done either on the flight line or in some other maintenance shop. Therefore, it becomes even more important to center the initial hole in the stud. It usually is best to use a pilot drill first, instead of using the tap drill to start with. That way, if you should miss the stud center slightly, you might be able to correct it with the tap drill. However, the best course of action to take is to select a drill size just *under* the tap drill size. Usually, stud threads will remain only on one side of the parent hole, and they can normally be removed with a scribe or sharp punch.

Many of the studs (and bolts) that you will be called on to remove will be harder than usual—especially around the hot section of jet engines. Sometimes it will be necessary to use carbide drill bits, but most of the time you can accomplish the job with a standard drill bit by following a few simple rules. First, make sure your drill bit is *sharp*, especially at the corners of the cutting edges. Put penetrating fluid on the stud if it is available, but *don't* strike the stud with a hammer (a common practice to aid the penetrating fluid in reaching the full length of the stud). The penetrating fluid will help to loosen the remaining threads after you drilled the stud out, but striking the stud with a hammer can cause the top surface of the stud to become even harder. When you begin drilling, use a slow drill speed and heavy pressure. Use a small amount of cutting oil, if available, and remove the drill bit from the stud periodically to prevent the stud from becoming too hot. Also, when the drill bit becomes dull, resharpen it. Continued use of a dull bit will generate unwanted heat and cause the stud to work-harden.

To remove studs that are secured by a lockpin, you must normally drill the pin out before you attempt to remove the stud. If you successfully remove the pin, the stud will usually come out quite easily. On studs where the lockpit cuts into the threads of the stud and parent metal, it is often easier to just drill the stud out completely rather than to try to drill out the pin. After the stud has been drilled out, the rest of the pin can usually be picked out with a scribe or sharp punch.

Trepanning. Another type of drilling that can be used to remove damaged studs is called trepanning. Trepanning is generally used when the parent metal around the stud has become so damaged that it is impossible to save the threads. You should use trepanning only as the last resort, since it involves making a replacement insert or installing a stud with oversize threads. Since commercial trepanning tools are not available, you will have to manufacture the cutter. Trepanning tools (see fig. 6-11) can be made to fit nearly any size of stud. The tool works like a hollow mill. The disadvantage of trepanning is that the original threads in the parent part are destroyed and oversize threads must then be tapped into the parent part. You should use this method only when there is absolutely no possibility of replacing the damaged stud with a standard-sized stud.

Exercises (047):

1. What is probably the most accurate method of drilling a broken or damaged stud?

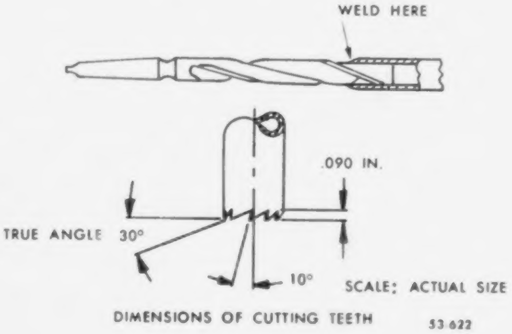


Figure 6-11. Trepanning tool.

2. What is the most important step in drilling a stud?

3. Why is it best to use a pilot drill first when you are removing a stud by drilling?

4. When drilling a stud that is especially hard, what should you make sure of concerning the drill bit?

5. What problem can be caused by using a dull drill bit when drilling a stud?

6. How should you remove a stud that has a lockpin that does *not* cut into the threads of the stud?

7. Why should trepanning be used only as a last resort?

048. Describe the procedures for replacing studs, and explain the techniques for making stud drivers.

Stud Replacement. Successful stud or insert replacement usually depends upon the removal of the faulty part. In most cases, if you encounter no trouble in the removal and the threads are not damaged in the parent part, it will be necessary only to clean out the mating threads with the correct size tap and make the replacement with standard parts. If you do encounter trouble during the removal and the thread in the parent part is damaged, it will be necessary to tap the parent part with an oversize tap and install an oversize part. There are occasions, however, when even if the part has been removed and there is very little damage to the parent part, you should use an oversize replacement part. This procedure is especially necessary on aircraft engine work where safety depends upon perfect threads in every part.

Before you attempt to replace a stud on aircraft or associated equipment, be sure to check the applicable technical order. Many times it will specify the use of oversize studs and give a replacement stud part number, or, in some cases, it will specify that no stud replacement is authorized and the whole part must be replaced.

When you must replace a flanged stud that was secured with a lockpin that does not cut into the threads, you should make a new pin hole instead of trying to reuse the old one. Using a new hole will help insure that the pin is tight when you drive it into the hole. If it isn't tight, the stud will be allowed to move slightly and this movement can cause the threads in the parent metal to be worn and enlarged.

To replace studs on which the lockpin cuts into the threads, it is best to insert the new pin in the same location, if possible, because each new hole will weaken the parent threads appreciably. You must be very careful when you attempt to redrill the hole, because you will be drilling only through the threads on the stud. This procedure can cause the drill bit to break quite easily. And *don't* just leave a broken drill bit in the hole as a substitute for the pin. For one thing, the drill bit is probably shattered and will not completely secure the stud. Also, when it becomes necessary to remove that stud, someone is going to have a difficult time trying to remove the broken bit. It's bad enough to have to correct one's own mistakes, but it's *really* irritating to have to repair someone else's!

Stud Drivers. One problem that you will run into when you must replace studs is how to insert them without damaging the threads on them. You can use a commercial stud removal and replacement kit, but, as we mentioned previously, these tools are usually too bulky to be used in many of the tight places that you will have to work in.

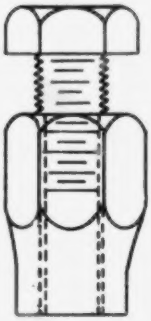


Figure 6-12. Locally made stud driver.

As an expedient stud driver, two nuts tightened together on the stud thread will usually suffice. However, if the stud is very tight during installation, the two nuts can cause damaging thread strain, since they must then be overtorqued in order to hold.

A better method is to make a set of stud drivers. Stud drivers are very simple to make and can be small enough to be used in almost any situation. Figure 6-12 is a sectional view of a typical stud driver. The thread size of the stud is tapped through a piece of hex steel, and a bolt is used to lock the driver in place on the stud. The driver (except the bolt) should be hardened slightly to prevent excessive wear, but it should not be harder than the stud that it is to be used on. It is best to have sufficient thread length in the driver so that the driver will accept at least 3/8 inch of the stud thread length. This thread allowance will help prevent stripping of the top few threads on the stud of the bottom few threads of the driver.

Exercises (048):

1. How is the replacement of a stud affected by the way the damaged stud was removed?

2. Normally, the lockpin should not be located in the same hole in the parent metal when replacing which kind of stud?

3. Why shouldn't a broken drill bit be left as a substitute for a lockpin?

4. List three types of suitable stud drivers.

5. When you are making a stud driver, why and to what extent should it be hardened by heat treatment?

6. A properly made and installed stud driver will utilize what length of the stud threads?

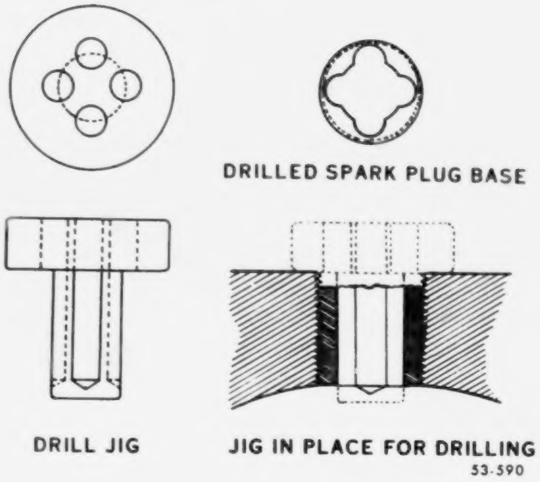


Figure 6-13. Spark plug drill jig.

049. Explain various procedures involved in removing broken spark plugs properly.

Methods of Plug Removal. Even though most aircraft in the Air Force today are powered by jet or turbine engines, you may still be called on occasionally to remove a broken spark plug from a reciprocating engine. It could be from either a small utility aircraft engine or the engine of a piece of ground equipment. No matter where it is, it is usually a difficult task. Normally, when you arrive on the job, all that will be left of the spark in the cylinder is just the lower threaded barrel; the ceramic center portion comes out when the plug breaks off. You can try a stud extractor first, since the hole is already through the plug remains, but don't count on much success. If the threads were corroded enough to break the plug, they probably won't move with the stud extractor either, even with a generous application of penetrating fluid. If the extractor method fails, there are a couple of alternative methods that you might try.

Use of drill jig. Figure 6-13 shows a typical drill jig for drilling the base or threaded portion of a broken spark plug. The four holes in the face of the jig guide a drill into the wall of the plug base. After the drilling is completed, you can remove the jig and tap the sections between the holes inward toward the center with a chisel to loosen the thread from the mating part. Sometimes, drilling the plug loosens it enough so that you can unscrew it by using an extractor of the proper size.

When you are working on a broken spark plug, you should prevent pieces of the plug from dropping into the cylinder. One way to do this is to pack a generous supply of grease in the center of the plug base (try not to drop any grease into the cylinder). As the pieces of the plug base break loose, the grease will hold them until you remove them with needle-nose pliers. If pieces of the plug should fall into the cylinder, be *sure* to inform the crew chief or person in charge of the equipment so that they can remove them before starting the engine.

Use of hacksaw blade. Another method of removing a broken plug base is to make four cuts into the walls of the base with a hacksaw blade. The cuts act exactly the same as the drilled holes in the jig method. Make each cut only deep enough to contact the parent threads and then follow the same procedures for removal as with the jig method.

NOTE: Since this method involves using a hacksaw blade without the hacksaw frame, you must protect your hand. If time permits, you can make a simple handle from a piece of wood or phenolic. When time is critical, wrap a piece of cloth around the portion of the blade that you will be holding and tape it securely. Be careful during the sawing operation because the blade will bend very easily and can cause injury to your hand.

Exercises (049):

1. Why is it logical to try a stud extractor first when you are attempting to remove a broken spark plug from an engine cylinder?

2. How does the drill jig aid in removing a broken spark plug?

3. How can you prevent chips and pieces of the plug base from falling into the cylinder?

4. What cylinder damage must you take care to prevent when removing a plug base by the hacksaw blade method?

5. When using the hacksaw blade method, what must you do to prevent injury to your hand?

050. Explain various simple screw-removal methods.

Much of the time you spend on the flight line will be spent removing screws. As with studs, some screws are very easy to remove and some are extremely difficult. In our discussion, we shall explain some of the easier methods.

Simple Screw Removal Methods. One of the first things to check before you attempt to remove a screw is the screw slot or apex socket in the screwhead. If the slot or socket is packed with dirt or paint, a screwdriver or apex will not seat properly and will not remove the screw. Many times, all that is needed is to pick out the dirt or paint with a scribe or a similar sharp-pointed object and then remove the screw with a screwdriver or speed handle and adapter.

Many people have trouble removing screws simply because they don't use enough pressure on the screwdriver or speed handle. The more pressure applied to screwdriver or speed handle, the harder it is for the tip of the tool to slip up and out of the screw slot or socket. You can apply much more pressure to a speed handle, (item A in fig. 6-14) than to a screwdriver. And you can modify a speed handle so that you can apply even more pressure than normally possible on it. Most speed handles have a handle of approximately ¼ inch diameter, which is not very comfortable to press on. By making a 2- or 3-inch diameter head (slightly convexed on the top surface), as shown in B of fig. 6-14, and pressing it onto the end of the handle, you can provide a palm-sized pressure pad that will allow you to lean into it and use your body weight as well as arm muscles to apply the needed pressure.

On certain types of screws (round-head capscrews, fillister head machine screws, etc.), the head of the screw is above the surface of the surrounding area. On these screws, a good pair of self-locking pliers (with jaw tips ground flat and even) can be used with must success by locking the nose of the pliers over the screw head. Be careful, though, as the jaw tips

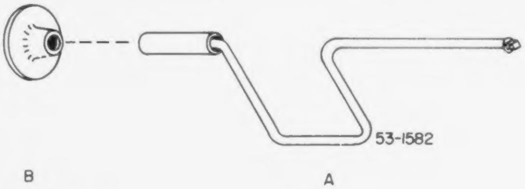


Figure 6-14. Speed handle and pressure pad.

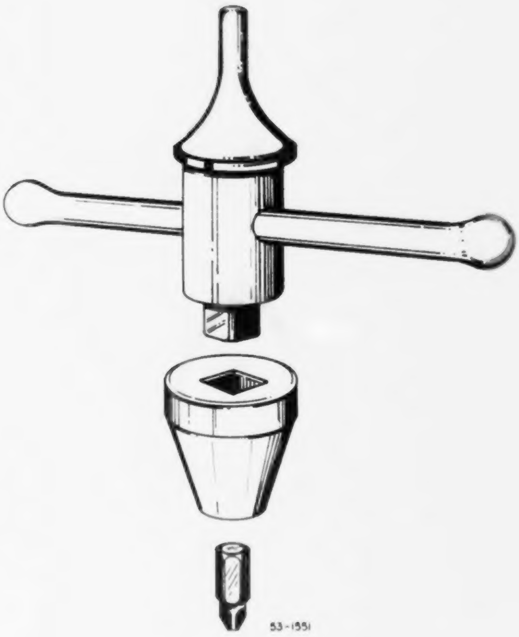


Figure 6-15. Apex adapter tool for pneumatic hammer.

can gouge the surrounding surface if the pliers are not held exactly in line with the axis of the screw.

Exercises (050):

1. How can a scribe be used to aid in removing screws?

2. What does pressure on the screwdriver or speed handle have to do with removing screws?

3. How can you increase the effectiveness of the standard speed handle?

4. What possible damage should you protect against when using self-locking pliers to remove screws?

051. Explain specific procedures and precautions to observe in using the pneumatic hammer to remove screws.

Using the Pneumatic Hammer. As we mentioned back in Chapter 5, the pneumatic hammer (fig. 5-11) can be used to speed up screw removal in certain cases. To use the pneumatic hammer for this purpose, you must have an adapter that will fit into the hammer receptacle and will hold the apex or screwdriver bit. A typical adapter is shown in figure 6-15. You can make a good adapter from an old rivet set by grinding a square drive on the end of it. The rivet set already has the correct shape on the hammer receptacle end and is already hardened.

Probably the most important thing to check before using the pneumatic hammer to remove screws is the amount and type of backing behind the surface containing the screws. NOTE: If the surface is *not solidly supported* by ribs or spars, then the pneumatic hammer *should not* be used. In areas that are not supported properly, the pneumatic hammer can drive the screw right through the skin or severely dent the area around the screw.

Once you have determined that the support is sufficient to use the hammer, you should adjust the air pressure in some way so that the hammer does not strike the adapter with full force. It isn't the force of the blows that breaks the screw loose so much as it is the rapid vibration, which tends to break up corrosion between the screw and the parent threads.

NOTE: Don't rotate the screw more than a quarter of a turn with the pneumatic hammer. If you turn it too far, the hammer blows can damage the threads in the parent part (usually a nut-plate, which can easily be knocked loose). After the screw has been loosened, remove it with a screwdriver or speed handle.

The pneumatic hammer can be used effectively to remove screws even though the screw slots or sockets are nearly stripped completely out. By maintaining a steady pressure on the tool and using a light turning pressure on the adapter, the striking of the hammer will normally reform the screw slot or socket sufficiently to allow the screw to be loosened.

You should always wear safety glasses when using the pneumatic hammer. The apexes or screwdriver bits break easily and the pieces will fly all directions when they do break. Also, be sure that the apex or bit is solidly in place in the screw *before* you start the hammer.

Otherwise, the apex or bit could bounce off the screw and damage the surrounding surface or cause injury to you.

Exercises (051):

1. What is the most important factor in determining whether a pneumatic hammer can be used to remove screws?

2. What can result from using the pneumatic hammer on screws that are not sufficiently supported?

3. Why isn't maximum striking force required to effectively loosen screws?

4. Why shouldn't a screw be completely removed with the pneumatic hammer?

5. What safety precautions should you take when using the pneumatic hammer?

052. Explain various procedures for making and using a screw punch, in conjunction with a hammer, to remove screws.

One of the standard ways of loosening corroded or overtorqued screws is to use a center punch and hammer on the outer edge of the screwhead to rotate it—and it *does* work in a lot of cases. However, the point of the punch usually does more gouging than rotating. The idea is good, but you can easily make a more efficient tool that we call a screw punch.

Making a Screw Punch. Figure 6-16 shows a typical screw punch. There are many ways to make one: form a lathe boring tool bit, a lathe parting tool bit, etc. However, the one pictured is especially well suited for the task since it has a solid steel handle similar to a chisel shank. This construction makes the screw punch easy to strike with a hammer and there is no danger of the tool bit shattering in your hand the way the other styles can. To make a screw punch like that shown in figure 6-16, use a 5- or 6-inch piece of hex steel (the hex shape is easier to keep from revolving in your hand) and a 3/8-inch high speed steel tool bit. A hole should be drilled in the end of the hex handle to a depth equal to at least half the length of the tool bit. The diameter should be slightly smaller than the dimension across the corners of the tool bit to allow the bit to be pressed tightly into the hole. The end of the tool bit to be pressed into the handle should be ground square and have all the sharp corners and edges rounded. After the tool bit is in the handle, you can grind the working end of the tool bit. Choose one of the end edges of the tool bit as the bottom edge and grind the end surface so that it slopes back from the bottom edge at approximately a 10° angle. This slope allows the bottom edge (the working edge) to dig into the screw head enough to prevent slipping but not so much that it acts like a chisel. The tool bit corners adjacent to the bottom edge should be rounded off to prevent them from digging into the area around a screw. Be sure to round the edge of the striking end of the handle. Just as with a chisel or punch, you must prevent the end of the handle from mushrooming. Since the tool bit can shatter, it is a good idea to wrap all but the last one-fourth inch in tape. This taping will prevent the pieces from flying around in case the bit does break.

Screw Removal. Using the screw punch to loosen screws is quite simple, as shown in figure 6-17. To start, hold the screw punch at about a 10°-15° angle to the axis of the screw, with the bottom edge of the tool bit near the outer edge of the screw and preferably in line with one of the screw slot extensions. (See fig. 6-17.) By striking the tool a couple of times in this position, the tool bit will be securely seated in the screwhead. Then the tool can be

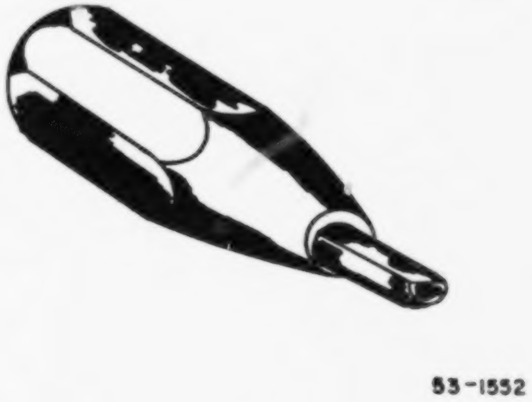


Figure 6-16. Locally made screw punch.

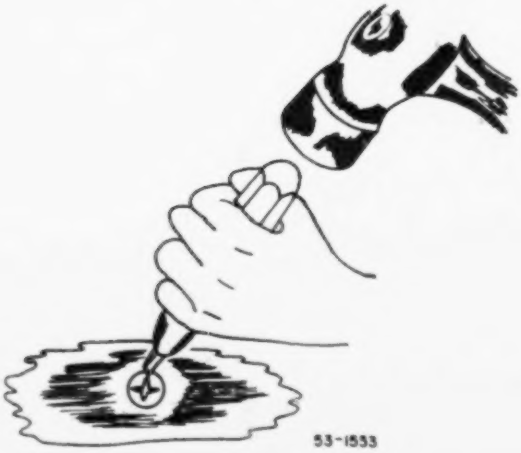


Figure 6-17. Using a screw punch and hammer for screw removal.

angled back about 30° to 45° to the axis of the screw. A series of light taps with the hammer usually does more to rotate the screw than heavy blows. With heavy blows, you run the risk of driving the tool off the screwhead and causing it to scratch or gouge the surrounding surface.

As with the pneumatic hammer, this tool should be used only where there is sufficient support behind the surface containing the screws. Also, the screw should be merely "broken loose" or turned about one-fourth of a turn with the screw punch in order to prevent damage to the nut-plate or parent thread. After it has been loosened, you can easily remove the screw with a screwdriver or speed handle.

Since the tool bit is subject to chipping or breaking, you should wear safety glasses when using this tool. However, if you use the tool properly, you should not have to do anything to it except resharpening the bottom edge periodically as it becomes dull.

Exercises (052):

1. What is the purpose of using hex stock to make the handle of the screw punch?

2. What diameter should be drilled in the handle for the tool bit?

3. The cutting edge and surface on the tool bit should be sloped back at what angle?

4. How can you prevent pieces of the tool bit from flying around in case the bit breaks?

5. What is the purpose of holding the screw punch nearly in line with the screw axis during the first couple of hammer blows?

6. Why should you *not* normally use heavy hammer blows on the screw punch?

7. What should you consider when determining whether or not to use the screw punch?

053. Describe the various methods of screw removal that involve drilling, and explain the techniques for restoring the threads in nutplates.

Screw Removal Methods Involving Drilling. There will be many instances when you must resort to drilling to remove damaged or corroded screws. For instance, on surfaces that are weakly supported, the pneumatic hammer, the screw punch, or even heavy pressure on a speed handle could cause damage to the surrounding area.

We shall discuss several ways in which drilling can be used to aid in removing screws, but it will be up to you to decide which method to use in any given situation. Even though a method might work well in one instance, it might be the worst choice in another similar instance.

Drilling off the screwhead. This method involves using a body drill to drill through the head and thus separate it from the body of the screw. This method is most useful when an entire surface panel is to be removed and several screws are badly damaged. By drilling the heads off, the panel can be removed, leaving the body of the screws extending slightly above the parent threads. Normally, you can easily remove the body of the screw with a pair of self-locking pliers. Be sure, however, that you *do* remove all of the screws after you have drilled the heads off. Don't stop after you have removed the panel: your job isn't complete until all of the screws have been removed.

Drilling for stud extractors. There will be times when you must drill the screw for a stud extractor (Ezy-Out). Be careful not to use too large a diameter drill; remember that the body of the screw is much smaller in diameter than the head. It is usually best *not* to drill the head of the screw off before drilling for an extractor, because the head will offer some support when you tap the extractor into the screw. On the other hand, the screw might be loosened sufficiently by removing the head to allow it to be removed with a minimum of pressure on the extractor. If you are using extractors made from tool bits, you might be able to remove some screws by holding the extractor in a ratchet-style (T-handle) tap wrench and by pressing it into the stripped screw socket. If the extractor is sharp, it might catch in the socket just enough to remove the screw.

If the head has been drilled off a screw and you must use an extractor to remove it, be sure that the hole for the extractor is completely through the screw (in case the extractor should break), and don't tap the extractor into the hole if the screw is in a nut-plate. The tapping can easily break the nut-plate loose. Instead, use the T-handle tap wrench (or its equivalent) as described above and apply only moderate pressure. If the screw still can't be removed, then you will probably have to drill the entire screw out.

Tap drilling. There will be times when drilling the entire screw out will be the only way of removing it. When this is the case, you must be very careful to protect the parent threads (usually a nut-plate). Here again, the success of the operation depends to a great degree on how well centered your first or pilot hole is. With a nut-plate, you have an added problem in that nut-plates can usually move around slightly or "float" in their sockets, making it difficult to keep the drilled hole straight with the axis of the screw. It usually is best to choose a final drill that is one size under the tap drill. This smaller size will help prevent thread damage in case your pilot hole was slightly off center.

Sometimes you will be lucky and the final drill bit will loosen the screw sufficiently so that the remaining threads will catch on the drill before it goes completely through and will spin through the nut-plate and drop off the drill in the area or cavity beyond the nut-plate. When this happens, you usually don't have to do anything else to the screw or nut-plate, but be sure to tell the person in charge of the unit because the thread pieces will have to be removed from the cavity. If the screw does not spin out of the nut-plate, then you can normally pick the remaining threads out with a scribe.

Restoring Nut-Plate Threads. Occasionally, the screw threads will be so corroded in the parent threads that you may not be able to completely remove them with a scribe. If the parent threads are not in a nut-plate but in solid metal, you can usually retap them to clean out the remaining screw threads. However, if a nut-plate is involved, it is a different story. The diameter of the lower end of a nut-plate is flattened slightly on two or more sides to form a locking device that prevents the screw from loosening by itself. This locking device is completely destroyed when a tap is run through it. Therefore, as a general rule, you would not normally retap a nut-plate.

There is a way, however, that you can use a tap to restore the threads in a nut-plate without destroying the locking device. You must use a tapered (starting) tap, but *don't* run the tap all the way through the nut-plate. You must be very careful to stop the tap *before* it cuts into the locking device on the end of the nut-plate. Usually, by running the tap in only that far, the remaining screw threads will be loosened from the nut-plate and will either come out with the tap or can be easily removed with a scribe. Use this method *only* as a last resort, since the risk of destroying the locking device is so great.

NOTE: You must be careful when you use a tap to clean out the remaining screw threads from parent threads, whether the parent threads are in a nut-plate or not. The tap can catch on a piece of screw thread, which can, in turn, cause you to break the tap. When the tap does catch, you can usually free it by carefully working it back and forth. The main thing is to *not* get impatient. Sometimes you might free it quickly and other times it might take several minutes. At any rate, it is usually easier to *free* the tap than to remove it after it breaks.

Exercises (053):

1. Under what circumstances would drilling off the head of a screw be most practical?

2. Normally, should the head of a screw be drilled off prior to using an extractor? Explain.

3. What tool allows you to put continuous pressure on an extractor when tapping it into the screw isn't practical?

4. What special problem do you encounter when you must drill a screw out of a nut-plate?

5. Why shouldn't you run a tap through a nut-plate to restore the threads?

6. How can a tap be used to restore the threads in a nut-plate without destroying the locking device?

7. Why is extra care necessary when you use a tap to clean out remaining screw threads from parent threads?

6-2. Inserts

Inserts provide a necessary function in the repair and manufacture of many parts. As a mechinist, you will be required to repair parts that require those inserts. In this section, we shall discuss two types of inserts: solid inserts and Heli-coil inserts.

054. Indicate the various types and uses of inserts.

Insert Types and Uses. The two types of inserts that are commonly in use in the Air Force are solid inserts and Heli-coil inserts. Solid inserts are produced in many shapes and sizes. Figure 6-18 shows a type of solid insert that is secured from rotating by a serrated lock-ring. Solid inserts are nearly always secured by some kind of locking device. In addition, some have an internal locking device such as the crimped lower threads shown on one example in figure 6-18.

Another type of solid insert is shown in figure 6-19. This type of insert is produced in the greatest variety of all. It can be flanged as the one pictured, or it can be straight, and it can be almost any length and diameter. The internal thread can be machined to accept nearly any type of stud or bolt. This type of insert is normally locked in place by the use of a dowel or lockpin, but some are secured by dimpling (similar to center punching) the parent metal around the top of the insert.

Solid inserts are used extensively to replace damaged threads, but they are also included in many production parts that are made of such metals as aluminum and magnesium. They effectively reduce the strain or pressure on the parent metal and also reduce the possibility of the stud's stripping out the mating threads.

The biggest disadvantage of solid inserts is that they take up a great amount of space in

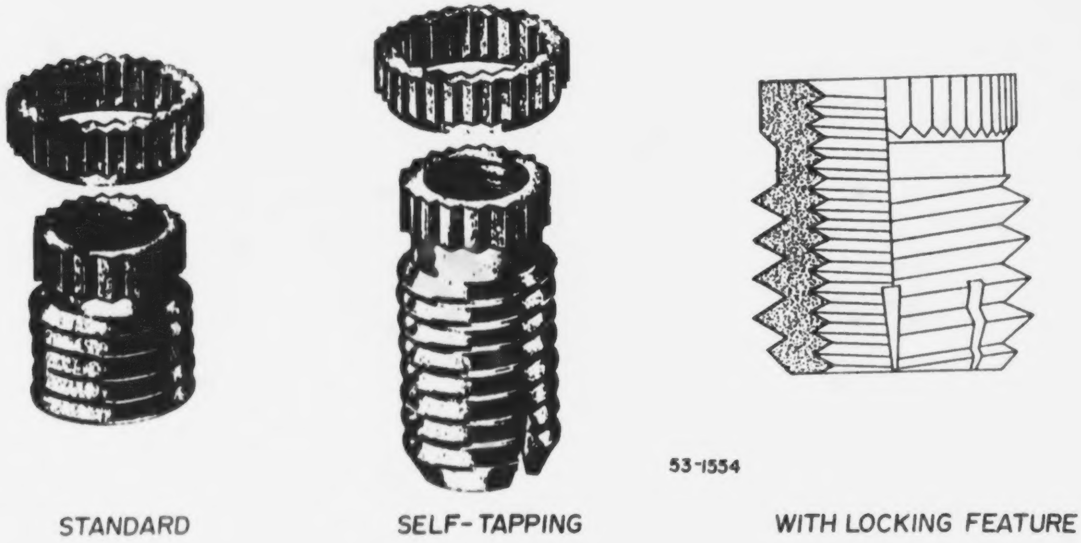


Figure 6-18. Lock-ring threaded inserts.

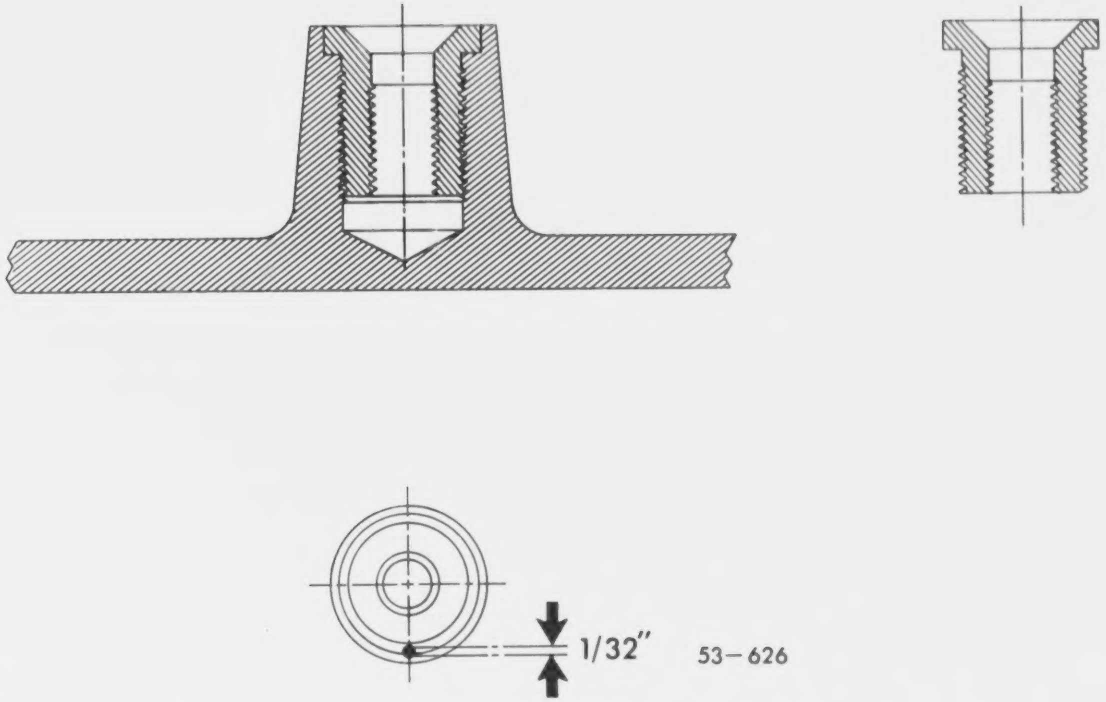


Figure 6-19. Solid inserts.

the parent metal. Normally, you will be directed by technical orders as to when and where to install them and also as to the exact size and type to use.

Solid inserts can be made from nearly any metal. However, bronze, stainless steel, and nickel steel are the ones used most commonly.

Another widely used type of insert is the Heli-Coil insert, shown in figure 6-20. It is a spring-shaped thread insert that is made of 18-8 stainless steel or phosphor bronze wire. A cross section of the wire in one of these inserts appears to have the shape of a diamond.

Heli-Coil inserts provide new threads that resist wear, corrosion, stripping, galling, and cross threading. On new equipment, Heli-Coil inserts help prevent thread failure before it starts. They reduce maintenance costs, and their great strength permits the use of smaller and fewer screws and bolts, smaller bases, and thinner flanges. They provide an inexpensive way to restore damaged or stripped threads to their original size. One advantage of Heli-coil inserts is the ease with which they may be removed and replaced. Another advantage is that the material that they are made of is harder than most screws and bolts. Therefore, if damage does occur, it is the screw or bolt that is damaged, rather than the insert. The smooth finish of the insert makes it desirable

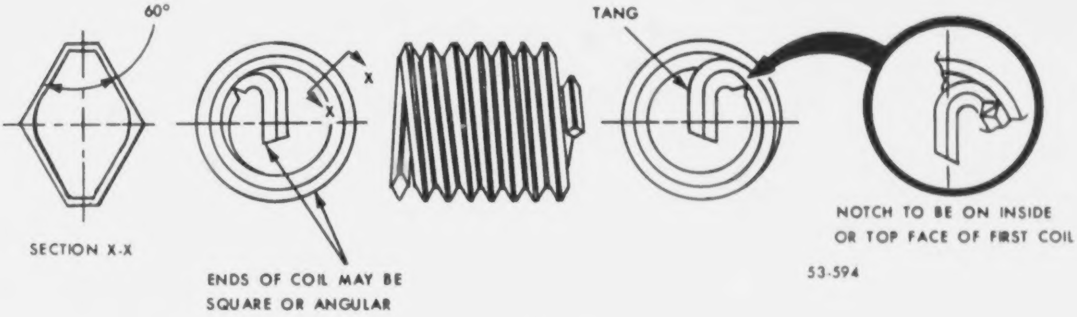

60°
SECTION X-X
X
X
ENDS OF COIL MAY BE SQUARE OR ANGULAR
TANG
NOTCH TO BE ON INSIDE OR TOP FACE OF FIRST COIL
53-594

Figure 6-20. Diagram of Heli-Coil inserts.

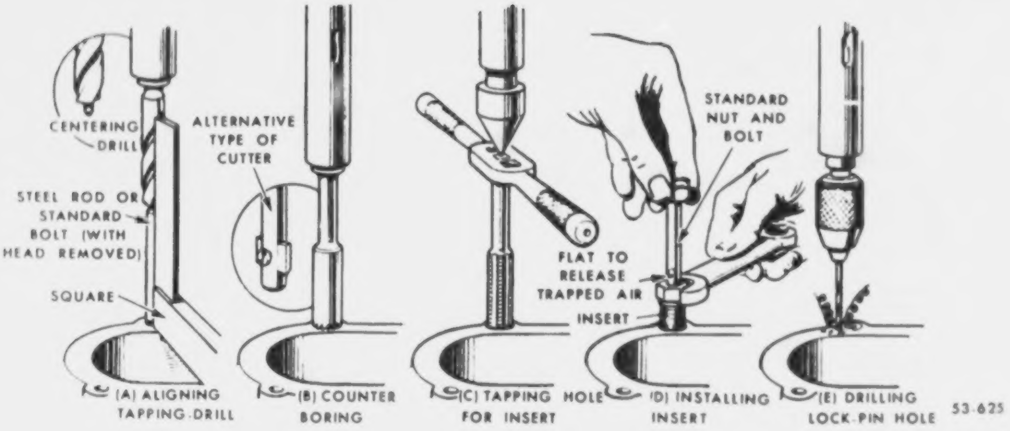

CENTERING DRILL
ALTERNATIVE TYPE OF CUTTER
STEEL ROD OR STANDARD BOLT (WITH HEAD REMOVED)
SQUARE
STANDARD NUT AND BOLT
FLAT TO RELEASE TRAPPED AIR
INSERT
(A) ALIGNING TAPPING DRILL
(B) COUNTER BORING
(C) TAPPING HOLE FOR INSERT
(D) INSTALLING INSERT
(E) DRILLING LOCK-PIN HOLE
53-625

Figure 6-21. Method of installing a solid insert.

for aircraft repairs because there is less danger of seizure of the mating screw threads. The smooth finish reduces thread strain and increases the tightness of the mating threads. Heli-Coil inserts are especially useful in soft materials, such as aluminum and magnesium.

NOTE: Stainless-steel screws or bolts should never be used in Heli-Coil inserts because of the strong possibility that the threads will seize.

Aircraft manufacturers are using the Heli-Coil insert more and more in the manufacture of airframes and engines, especially in the later models of jet aircraft.

Just as with solid inserts, some Helti-Coil inserts are produced with locking devices for securing the stud. Also, they are made in almost all thread sizes, including metric. They require much less space than do solid inserts, but they have a disadvantage in that they cannot normally be used where it is necessary to seal off air or liquid pressure around the threads. An O-ring seal (a sort of round rubber washer) can be used effectively with solid inserts, but it cannot effectively be used with Heli-Coil inserts.

Exercises (054):

1. What are the various ways that solid inserts can be secured or held in place?

2. Why are solid inserts sometimes installed on new parts?

3. What is the main disadvantage of solid inserts?

4. Heli-Coil inserts are made of what materials?

5. On what metallic materials are Heli-Coil inserts especially useful?

6. What is the biggest disadvantage of Heli-Coil inserts?

055. Explain the installation and removal methods for solid inserts.

Solid Insert Installation. Installing a solid insert can be a simple task or a fairly complicated one, depending on the style of insert used. Figure 6-21 shows the procedure for installing a flanged solid insert. The depth of the counterbored hole is a critical dimension. If it is not deep enough, the flange of the insert will extend above the surface of the parent part, causing improper seating of the mating part. If this situation isn't noticed, it can even cause one of the parts to break when the parts are torqued together. It is best to have the top surface of the flange seated 0.0002 or 0.0003 inch below the surface of the parent metal. The insert in figure 6-21 is secured by a lockpin, which is usually made from a stainless-steel rod about 1/16 inch to 3/32 inch in diameter (or even larger in the case of very large inserts). Some of the larger inserts are secured with threaded lockpins.

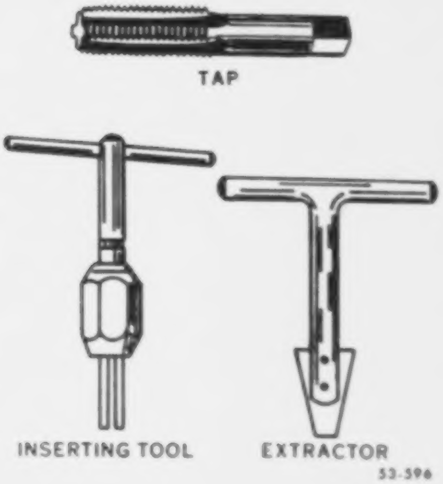


Figure 6-22. Heli-Coil handtool set.

The seat for lock-ring inserts is prepared in much the same way as for flanged inserts, except that the counterbore for the ring is deeper than the thickness of the ring. This difference is necessary to provide clearance for the burrs created under the ring when the serrations on the outer diameter of the ring cut into the parent metal during installation. The ring should be installed flush with the parent surface, but the insert should be a few thousandths of an inch below the parent surface.

No special tools are required to thread a solid insert into a prepared seat. Usually a bolt and a nut can be used, as shown in figure 6-21.

Solid Insert Removal. Removing a solid insert is usually more difficult than installing it. To remove a flanged or straight insert that is secured by a dowel type lock-pin, you must first remove the pin. Although pin removal is normally accomplished by drilling the pin out, this method is difficult because the pin is so small in diameter and is usually made of a tougher material than the parent metal. However, once the lockpin is removed, the insert will usually come out quite easily by using a stud extractor.

To remove an insert of the lock-ring type, drill the neck of the insert to a depth just below the bottom of the ring, using a drill at least as big as the minor diameter of the serrations on the insert. This action will free the insert from the lock-ring and will allow you to pry the ring out of the parent metal. Once the ring is removed, the insert usually can be removed without difficulty by using a stud extractor.

When the threads in the parent metal or other parts of a solid insert seat are damaged to the extent that the seat cannot be used again, it is imperative that you be extremely careful to protect the parent threads and seat when you remove a solid insert.

Exercises (055):

1. Why is the depth of the counter-bore considered critical for a flanged solid insert?

2. How does the top surface of a properly installed solid insert compare with the surrounding surface of the parent metal?

3. Why is the depth of the counterbore for a lock-ring insert deeper than the thickness of the ring?

4. What tool is normally used to thread a solid insert into the parent metal?

5. Why is insert removal usually more difficult than insert installation?

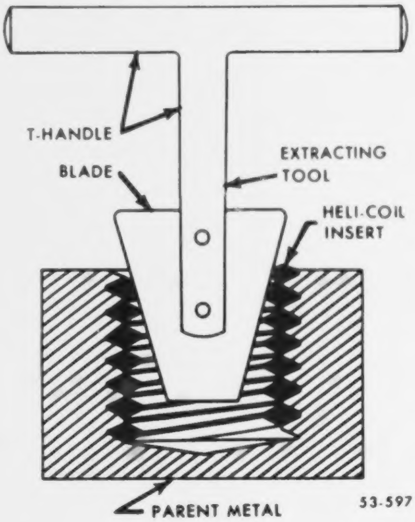


Figure 6-23. Use of the Heli-Coil extracting tool.

6. Explain how to remove the lock-ring when a lock-ring insert must be removed?

7. When you must remove a solid insert, why should you be *especially* careful not to damage the parent threads?

056. Explain the installation and removal procedures for Heli-Coil inserts.

Heli-Coil Insert Installation. The use of Heli-Coils requires some special tools, the most important of which is the tap. (See fig. 6-23.) Each size of Heli-Coil insert has its own special tap. Also, each Heli-Coil size has a particular size of inserting tool. The standard inserting tool prewinds the Heli-Coil (compresses it to the same size that it will be when installed) in a threaded tubular portion, and a slotted center shaft is used to wind the insert into the parent threads. If your shop does not have a Heli-Coil tap drill chart, you can obtain this information, as well as other information about the use of Heli-Coils, from Technical Order 44H-1-117, *General Installation of Heli-Coil Inserts.*

There are several important things to remember in installing Heli-Coils. You should always use the correct tap drill size for the size of Heli-Coil that you are installing. Some Heli-Coil taps come in two sizes, roughing and finishing, and are marked as such on the tap shank. If you rough-tap the hole and install the Heli-Coil, the screw or bolt will not screw into it. Therefore, be sure that you use a finishing tap before installing the Heli-Coil. Also, the Heli-Coil should be installed so that the top coil is approximately a half turn below the parent surface. This distance insures that the top coil is seated in a full thread groove and helps to prevent the Heli-Coil from stripping out.

After installing the Heli-Coil, you must remove its drive tang. There is a special tool called a tang breakoff tool that you can use. If a tang breakoff tool is not available, you can use a drive pin punch and hammer. The drive pin punch should be slightly smaller than the minor diameter of the Heli-Coil. If the minor diameter of the Heli-Coil permits, a pair of long-nosed pliers can be used to break the tang off. You should never use the inserting tool to break off the tang, because the tool could break or the bottom thread of the Heli-Coil could be damaged. If the Heli-Coil or its broken off tang is accidentally dropped into an inaccessible area, you can use a small magnet to retrieve it. When you break a tang off in a blind hole, it can easily removed by placing a small spot of grease on the shank end of a small drill bit and then placing the greased drill bit in contact with the tang. The tang will adhere to the grease and can be lifted out of the hole. Never leave the tang in the hole after it is broken off: it could cause the bolt or stud to be stripped during installation.

Heli-Coil Insert Removal. Removing a damaged Heli-Coil is a fairly simple matter. Figure 6-23 shows how a standard Heli-Coil extractor is used. Each extractor tool has a certain range of insert sizes that it can be used on (usually marked on the tool). The extractor tool should be used with hand pressure only and should not be driven into the insert with a hammer. The blade edges can be easily damaged when the tool is seated with a hammer. Before you attempt to remove the insert, check to see whether the parent metal has been dimpled in front of the top thread of the Heli-Coil. If it has been, you must remove whatever metal is blocking the insert thread before the insert can be efficiently removed. A stud extractor made from a tool bit can also be used to remove a Heli-Coil insert when a standard extracting tool is not available.

NOTE: Never pull a Heli-Coil insert straight out with a pair of pliers. This practice can damage the parent threads to the extent that they cannot be used again.

Exercises (056):

1. What three tools are normally required for Heli-Coil installation?

2. Which of the three tools referred to in exercise 1 is the most important?

3. What can be used in place of a standard tang breakoff tool?

4. How should the Heli-Coil extractor tool be seated for insert removal?

5. What should you do prior to attempting to remove a Heli-Coil insert?

6. What can result from pulling a Heli-Coil straight out?

Bibliography

Books

OBERG, Erik, and Franlin D. JONES. *Machinery's Handbook,* Nineteenth Edition. New York: Industrial Press, 1974

COLVIN, Charles H., Henry F. COLVIN, and Eleanor STANLEY. *The New American Machinist's Handbook.* New York: McGraw-Hill Book Company, 1973.

WALKER, John R., *Modern Metalworking.* Illinois: The Goodheart-Willcox Company, Inc., 1973.

Department of the Air Force Publications

AFR 205-1, *Information Security Program* (Supplements DOD 5200.1-R).

AFM 39-1, Volume 2, *Part Two—Airman Classification Manual.*

AFM 67-1, *USAF Supply Manual.*

AFM 67-23, *Standard Base Supply Customer's Manual.*

AFM 127-101, *Accident Prevention Handbook.*

TO 1-1A-8, *Structural Hardware.*

TO 32-1-101, *Maintenance and Care of Handtools.*

TO 32-2-151, *Hand, Measuring, and Power Tools.*

TO 44H1-1-117, *General Installation of Heli-Coil Inserts.*

NOTE: None of the items listed in the bibliography above are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell AFB, AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only *books* and a limited number of *AFMs*. TOs, classified publications, and other types of publications are not available. Refer to current indexes for the latest revisions of and changes to the official publications listed in the bibliography.

Answer for Exercises

CHAPTER 1

Reference:

001 - 1. The metalworking career field.
001 - 2. To refer to all skill levels within an AFS.
001 - 3. The zero in 53130, in conjunction with the other digits, designates the machinist specialty within the metalworking career field.

002 - 1. Formal technical school training, on-the-job training at an assigned duty station, or successfully completing a bypass specialist test.
002 - 2. 53150.
002 - 3. 7 skill level—SSgt (E-5); 9 skill level—MSgt (E-7).
002 - 4. Develop good study habits.

003 - 1. Taking an active interest in his upgrade training and producing quality workmanship in all aspects of his job.
003 - 2. Manufacturing and reworking machined parts, assembling and fitting machined parts, maintaining hand and machine tools, and supervising machine shop personnel.
003 - 3. An apprentice machinist (3 level) is responsible only for his own actions and workmanship, whereas a machinist (5 level) may be held responsible for the actions and workmanship of others as well as himself.

004 - 1. a.
004 - 2. b.
004 - 3. a.
004 - 4. a.
004 - 5. b.

CHAPTER 2

005 - 1. Classified, unclassified, and of possible intelligence value.
005 - 2. Classified.
005 - 3. Unclassified.
005 - 4. No.
005 - 5. Of possible intelligence value.

006 - 1. Top Secret.
006 - 2. Unclassified (For Official Use Only).
006 - 3. Confidential.
006 - 4. That information which, if disclosed, could result in serious damage to the national security.

007 - 1. Telephone.
007 - 2. By the use of official codes and ciphers.
007 - 3. The material sent by messenger is secure, requires receipts, and is not usually subject to inspection; however, material sent by messenger tends to be slower and more expensive than some other forms of transmittal.
007 - 4. Registered mail.

008 - 1. Operational security.
008 - 2. To combine all previous DOD security programs into one effective overall security program.
008 - 3. Discussing sensitive information by implying the meaning rather than actually saying it.
008 - 4. Do not use homemade codes in an attempt to disguise sensitive information, and do not discuss official or job related information in insecure or public places.

009 - 1. From the base supply unit.
009 - 2. To purchase and provide the required supplies in a timely manner and to ensure that they are controlled, protected, and accounted for.
009 - 3. By requesting only needed supplies and by using those supplies wisely.

010 - 1. DD Form 1574, Serviceable Tag—Material; DD Form 1577-2, Unserviceable (Reparable) Tag-Material; and DD Form 1577, Unserviceable (Condemned) Tag—Material.
010 - 2. That the piece of equipment is condemned and should not be used.
010 - 3. Yellow tag (DD Form 1574).
010 - 4. Green tag (DD Form 1577-2).

011 - 1. The Federal Supply Classification (FSC) code and the national item identification number (NIIN).
011 - 2. 77; they are represented by the first two digits in the NSNs.
011 - 3. H2-1, *Cataloging Handbook*.
011 - 4. In S-2A-1.
011 - 5. The IL (identification list) for the particular FSC.
011 - 6. The supply research section.
011 - 7. a. AF Form 2005.
b. AF Form 601b.

c. AF Form 601b.
d. DD Form 1348-6.

012 - 1. There aren't any.
012 - 2. By storing them in wood-lined drawers or cabinets, hanging them on shadow boards with separators, or coating them with plastic in a hot-dip tank.
012 - 3. Be careful not to get oil film on tool handles or grips.
012 - 4. Waist height.
012 - 5. In a properly designed shed or building outside of the shop.
012 - 6. To prevent someone from tripping over the items.

013 - 1. Property accountability. Property responsibility.
013 - 2. Both would be responsible.
013 - 3. Checking to be sure that each listed item is physically on hand.

014 - 1. $250.
014 - 2. When an individual declines to or cannot afford to pay cash, in which case it must be collected through payroll deductions.
014 - 3. An individual may be allowed up to 25 percent of the cost of the item for depreciation.

015 - 1. To explain and record circumstances that involve the loss, damage, or destruction of Air Force property and to resolve questions of responsibility and fix liability.
015 - 2. Normally, the property custodian.
015 - 3. 30 days.

CHAPTER 3

016 - 1. Flying chips, sharp tool and work edges, and slippery surfaces.
016 - 2. Because they cannot be replaced.
016 - 3. Safety glasses, goggles, face shields, safety boots, and gloves.
016 - 4. Tiny metal particles produced by a grinding operation are propelled in many directions at once.
016 - 5. Loose-fitting jackets, ties, finger rings, bracelets, necklaces, key chains and wristwatches.
016 - 6. Check the machine before starting, making sure that machine guards are in place and that the shutoff switch can be quickly reached.
016 - 7. You can't operate a machine safely or efficiently when your attention or concentration is divided.

017 - 1. Because most fires are caused by the careless disposal of combustible materials, such as smoking materials.
017 - 2. In a metal container that has a self-closing lid and is designated for soiled rags only.
017 - 3. Chlorobromethane (CBM) if this type is available and the area is open; otherwise, use the carbon dioxide (CO2) type.
017 - 4. Either a dry powder extinguisher or dry sand.
017 - 5. Notifying the fire department immediately.

018 - 1. Earplugs and muffs. Because a person's ears can gradually become permanently damaged by the high-frequency sounds without the person's knowledge of it.
018 - 2. Frostbite. Sunburn and heatstroke.
018 - 3. Jet exhaust, jet intake, and turbine wheel disintegration.
018 - 4. The faster a propeller spins, the more invisible it becomes.
018 - 5. High-powered jet engines can produce noise loud enough to cause tension to build quickly to the breaking point in an individual, leaving lasting adverse effects.
018 - 6. Because certain parts in newer aircraft are radioactive and because x-ray is being used more and more as a metal inspection technique.
018 - 7. The 00-110 series technical orders.

019 - 1. The supervisor.
019 - 2. To gather all the facts surrounding an accident to aid in determining the cause.
019 - 3. Unsafe acts or conditions.
019 - 4. The supervisor must make a complete report to the ground safety office and must determine what measures will be effective in preventing a recurrence of the accident.

020 - 1. It refers to a copy of an original engineering drawing. Technically, it also refers to a particular kind of copy in which the lines are white on a blue background.
020 - 2. They are reproduced on microfilm and mounted on IBM cards. The cards are indexed by part number.
020 - 3. Five of the following:the name of the drawing, the scale of the drawing, the kind of material required, the heat treatment required, the tolerances, the organization responsible for producing the drawing, the name of the engineer or draftsman, the date of the drawing, and notes on the finish required.
020 - 4. A listing of the various parts used in the particular assembly depicted in the drawing.
020 - 5. Working drawings, assembly drawings, and exploded drawings.
020 - 6. A working drawing.
020 - 7. A unit assembly drawing depicts a completely assembled unit and is usually a cutaway drawing that shows all of the internal parts in their assembled positions.
020 - 8. An exploded drawing. It is used to identify the various parts within an assembly by part number and to show the relationship of the various parts in an "exploded" or "taken-apart" view of the assembly.

021 - 1. In a combination of top, side, and front views.
021 - 2. As many as necessary to present all of the details of the object.
021 - 3. Our eyes view objects in perspective, while in orthographic projection, each view is presented as a true view.
021 - 4. Front.

022 - 1. Centerline.
022 - 2. Leader lines.
022 - 3. Phantom, reference, or datum lines.
022 - 4. Border lines.
022 - 5. Short break lines.

023 - 1. To show the true shape of a slanted surface that does show true in any normal view.
023 - 2. With crosshatching lines.
023 - 3. Partial sectional view.
023 - 4. Offset sectional view.
023 - 5. Yes. When it might be misleading to show a rib or web in its true position, it can be shown in an aligned sectional view.
023 - 6. Two of the parts are crosshatched with the standard 45° lines but slanted in opposite directions. The third part is crosshatched with lines set at 30° or 60°.

024 - 1. The location of radii and centers of circles.
024 - 2. Tolerance.
024 - 3. Bilateral.

024 - 4. Unilateral.
024 - 5. The intentional difference in the dimensions of mating parts.
024 - 6. The diameter of the thread, the number of threads per inch, the thread series, and the class of fit.
024 - 7. a. The surface is to be ground.
b. The surface is to be rough machined.
c. The surface roughness should be no more than 40 microinches and the surface waviness should be no more than three one-thousandths of an inch.

025 - 1. The meter and the millimeter.
025 - 2. 0.4878 inch.
025 - 3. 88.9 millimeters.
025 - 4. Because 0.01 millimeter is equal to 0.0004 inch, which is usually sufficient accuracy for such drawings.
025 - 5. 8.40 θ.

026 - 1. A pencil and paper.
026 - 2. Artgum and pink pearl.
026 - 3. The same standards that apply to mechanical drawings and blueprints.
026 - 4. Isometric and oblique.
026 - 5. Place a dot at the starting point and another at the point where you want the line to end. Then, after a number of practice swings, use a series of short strokes to connect the two dots.
026 - 6. Rest your second finger on the paper at the center of the proposed circle.

027 - 1. A loose hammerhead and a chipped or burred face.
027 - 2. The included angle is larger (90°) on the center punch than on the prick punch (60°).
027 - 3. Use the largest diameter punch that will satisfactorily do the job.
027 - 4. A hard blow has a tendency to bend the punch or mushroom the item being driven (pin, bolt, etc.).
027 - 5. 70°.
027 - 6. Grind off any mushroom burrs from the striking end and regrind the working end if it is dull or damaged.
027 - 7. On the cutting edge of the chisel.

028 - 1. The screw slot can be damaged.
028 - 2. The common or flat-tipped screwdriver. It can be reground, provided it isn't overheated.
028 - 3. Well back of the pivot joint (with the greatest pressure on the last quarter of the handles).
028 - 4. Never attempt to cut anything that is too hard to file easily.
028 - 5. The adjustable jaw can spring, causing the wrench to slip off the nut.
028 - 6. Because the larger the wrench, the greater the odds are that the bolt and/or nut will be damaged.
028 - 7. The screw socket can be damaged to the point that other (more difficult) removal methods would be required.
028 - 8. Indicating and breakaway.
028 - 9. The extension will cause the torque value to be different from that shown on the wrench.
028 -10. Make sure that it is reset to its lowest torque settings.

029 - 1. An all-hard blade.
029 - 2. Yes. Instead of cutting straight across the edge of the material, cut with the blade at an angle of about 45° to the work. (This saw position will increase the length of cut; however, you must still be very careful at the end of the cut, where you can't control the length of cut anymore.)
029 - 3. 32 teeth per inch.
029 - 4. File a notch on the work first.
029 - 5. The blade could be broken or teeth could be stripped from it.

030 - 1. The 10-inch file is coarser.
030 - 2. The clogging of the teeth of the file with chips and particles.
030 - 3. They are both; the faces are double cut and the edges are single cut.
030 - 4. The pillar file. It is used for filing keyways and slots.
030 - 5. Vixen and lead-float files.
030 - 6. The half-round bent scraper.
030 - 7. Rub a light coat of venetian red or prussian blue on the surface plate. Then rub the work surface over the surface plate. Paint will adhere to the high spots.
030 - 8. The paint spots will be increasing in number and decreasing in size.

031 - 1. Yes, with practice; however, if the measurement is critical, a more accurate tool should be used.
031 - 2. The depth gage.
031 - 3. The depth gage.
031 - 4. Because it actually makes contact with the two points being measured.
031 - 5. There are no graduations. The square is used to check the squareness of angles, not linear measurement.
031 - 6. A right angle (90°).
031 - 7. All three of them.
031 - 8. The protractor head in combination with the scale.
031 - 9. Regrind and hone it to a sharp point, and then grind and hone the other leg to the same length.
031 -10. The skill and experience of the operator and the accuracy of the measuring tool used in conjunction with the calipers.

032 - 1. Because they do not present as big a fire hazard as do the electrical tools nor do they involve the potential for electrical shock.
032 - 2. By removing moisture, by using rust-preventive sprays, and by putting a few drops of oil into the air intake periodically.
032 - 3. By attaching it to the drill motor with a short cord.
032 - 4. The hammer receptacle could be damaged or the tool could become lodged in the receptacle.
032 - 5. The possibility of a grinding wheel exploding. Wear goggles and a face shield, and use protective shields or curtains around the grinding area to protect other personnel in the shop.
032 - 6. Because the sparks produced by the grinding operation could easily ignite a disastrous fire.

033 - 1. 40 threads per inch.
033 - 2. 0.075.
033 - 3. 0.025.
033 - 4. 0.0001.
033 - 5. Turn the spindle into contact with the anvil. It should read exactly "zero".
033 - 6. It can cause scratches on the spindle and anvil, it can cause the spindle to bind in barrel, and it can cause play to develop in the spindle because of the abrasive action of the dust on the threads.

034 - 1. To measure the inside dimensions of slots or holes.
034 - 2. The tool can come apart and the small compression spring can be lost.
034 - 3. Because the measuring surface of the small hole gage is not a true circle. (The true reading can only be obtained over the largest diameter of the page.)
035 - 1. The graduations on the barrel are reversed. The largest measurement is nearest the head on the depth micrometer and nearest the end of the handle on the outside micrometer.
035 - 2. The extension rod.
035 - 3. 3.755 inch.
035 - 4. The micrometers could be damaged by the abrasive action of the dirt and dust, and the readings could be erroneous.

036 - 1. A vernier caliper can take the place of an inside micrometer and several outside micrometers.
036 - 2. 0.001 inch.
036 - 3. The offset attachment.
036 - 4. The vernier gear tooth caliper.
036 - 5. 5 minutes.

037 - 1. Four readings, 90° apart.
037 - 2. Its capacity (spindle movement limitations).
037 - 3. It receives nearly the same shock that the work receives, which can destroy the accuracy of the indicator.

038 - 1. It is handscraped after being machined.
038 - 2. It is used with other instruments (1) to check the accuracy of various gages and measuring instruments and (2) to check the accuracy of machined parts.
038 - 3. Keep the surface lightly oiled and covered.
038 - 4. The bench plate is not as accurately machined and finished as a surface plate.
038 - 5. The surface smoothness and flatness can be destroyed.

039 - 1. Plus 0.000010 inch and minus 0.000006 inch per length of block.
039 - 2. It is engraved on the block.
039 - 3. To insure that the total measurement over two or more blocks equals no more than the sum of the specified sizes of the blocks.
039 - 4. The acid from your hands acts as a corrosive agent.
039 - 5. The blocks must be completely free from dirt or grit.
039 - 6. You can use them to set up toolmaker's buttons and sine bars, to check the accuracy of various precision measuring instruments, and to act as a standard for setting up comparison instruments.

040 - 1. The hypotenuse.
040 - 2. 10 x 0.53509 = 5.3509 inches in height; 5 x 0.53509 = 2.67545 inches in height.
040 - 3. It should be protected from corrosion by a thin film of oil and then placed under a protective cover.

041 - 1. To prevent other buttons from interfering with the dial indicator in cases where two buttons are located very close to each other.
041 - 2. Because you can not depend completely on layout lines for precision machining. Layout lines should be used only as a reference for approximate locations when great precision is required.
041 - 3. 1.875 inches.
041 - 4. 2.875 inches.
041 - 5. By using a dial indicator on the button and moving the work until the required tolerance is attained.

042 - 1. Heavy applications tend to flake off when lines are scribed, leaving jagged, inaccurate lines.
042 - 2. Because they are also used to support work during machining operations.
042 - 3. Because it may have been reground to restore the surface finish but not remarked as to size.
042 - 4. To support and secure round stock.
042 - 5. By the use of C-clamps or parallel clamps.
042 - 6. Too much pressure can cause the surface gage setting to move and cause excessive wear on the scriber point.
042 - 7. Trammel points.
042 - 8. Wipe away all dust and grit from the surface plate, the vernier height gage, the work piece, and any other tools to be used.
042 - 9. To avoid carrying any errors in the overall dimension into the layout work within the part.

CHAPTER 6

043 - 1. Because they are deeper and stronger.
043 - 2. By using a stud on which the pitch diameter is slightly larger than on the original stud.

043 - 3. By the use of one or more lockpins.
043 - 4. The serrations (or teeth) on the outer diameter of the ring cut into and grip the parent metal while the inner teeth lock on the mating teeth on the stud.

044 - 1. Protecting the parent threads.
044 - 2. Do not allow the fluid to contact electrical wiring, and check the label on its container to see which metals it should not be used on.
044 - 3. Breaking the scribe point by applying too much pressure.
044 - 4. A portion of the stud surface mushrooms into the parent threads, locking the stud even tighter.
044 - 5. When it is difficult to make working space directly over the stud.
044 - 6. Grind the nose of the jaws so that the jaws are flat and even when in the closed position.

045 - 1. It is smaller, more effective on studs that extend only slightly, stronger, cheaper, and more easily replaced.
045 - 2. By plugging the center hole and drilling a series of equally spaced holes, using the plug's outer diameter as the hole circle, and then removing the plug.
045 - 3. 9 holes.
045 - 4. As the tool is driven onto the stud, the splines cut into the stud threads and provide a positive grip on the stud.

046 - 1. It should be centered in the stud.
046 - 2. ¼-inch drill.
046 - 3. With two wrenches placed opposite each other on the extractor shank so that the pressure applied will be even.
046 - 4. Overheating can cause the tool bit to break during use.
046 - 5. It can cause the stud walls to break, making stud removal more difficult, and it may damage the parent threads.

047 - 1. Using a drill jig.
047 - 2. Centering the initial hole.
047 - 3. It allows an opportunity to correct any mistakes in centering the hole before the parent threads are accidentally damaged.
047 - 4. Be sure that the drill bit is sharp to start with and resharpened as it becomes dull.
047 - 5. Using a dull bit can cause the stud to work-harden.
047 - 6. Drill out the lockpin. Usually, the stud will then come out easily.
047 - 7. Because it completely destroys the parent threads.

048 - 1. If the stud has been removed properly and without difficulty, it can usually be replaced without any special preparations.
048 - 2. A flanged stud in which the lockpin does not penetrate the threads.
048 - 3. Because it may be shattered over its full length and will not hold. Also, the next time that the stud must be removed, it will be nearly impossible to drill the pin out.
048 - 4. Commercial stud kit, two nuts locked together on the stud, and a locally made stud driver.
048 - 5. It should be hardened to prevent excessive wear but it should be no harder than the studs that it will be used on.
048 - 6. At least 3/8 inch.

049 - 1. The hole is already in the plug base and if the plug should come out with the extractor, it will save a lot of time.
049 - 2. It aligns the drill for drilling into plug walls without cutting into the parent threads.
049 - 3. By plugging the lower end of the plug base with grease, to which the chips will adhere.
049 - 4. Damaging the parent threads by cutting too deeply into the plug base.
049 - 5. Provide some type of handle with which to hold the blade.

050 - 1. To clean out the screw slot or socket.
050 - 2. The pressure prevents the driver from riding out of the socket when the screw is rotated.
050 - 3. By making a pressure pad for the handle.
050 - 4. Scratches on the surrounding surface by the nose of the pliers' jaws.

051 - 1. The support of the area around the screws.
051 - 2. The surrounding area can be dented or the screw can be forced through it.
051 - 3. Because the vibration rather than heavy blows is what breaks the screw loose.
051 - 4. After about one-fourth turn with the pneumatic hammer, the blows will begin to damage the parent threads or nut-plate.
051 - 5. Wearing safety glasses and making sure that the tool is in contact with the screw before it is started.

052 - 1. It provides a nonslip grip for holding the tool.
052 - 2. A diameter equal to slightly less than the distance across the corners of the tool bit to be used.
052 - 3. A 10° angle.
052 - 4. By wrapping all but the last one-fourth inch of the bit in tape.
052 - 5. To seat the bit securely in the head of the screw.
052 - 6. Heavy blows can cause the punch to slip off the screw head and damage the surface around it. Also, a series of light blows will usually do a better job of loosening the screw.
052 - 7. The amount of support under the area containing the screw.

053 - 1. When an entire panel that contains several damaged screws is to be removed.
053 - 2. No. The head will offer added support when the extractor is being seated in the screw.
053 - 3. A T-handle type of tap wrench.
053 - 4. Nut-plates normally "float", making alignment difficult.
053 - 5. Because the locking device will be destroyed by the tap.
053 - 6. By using a tapered tap and stopping it before it cuts into the locking device. This action loosens any remaining threads sufficiently to allow them to be picked out with a scribe.
053 - 7. The tap can catch on a piece of thread and break.

054 - 1. They can be secured with one or more lockpins or by lock-rings.
054 - 2. To strengthen the threads and to reduce thread strain on the parent metal.
054 - 3. They take up a great amount of space in the parent metal.
054 - 4. Phosphor bronze or stainless steel.
054 - 5. Aluminum and magnesium.
054 - 6. They cannot be used in places where air or liquid pressure must be sealed off.

055 - 1. If the counter-bored hole isn't deep enough, the parts can be damaged when they are bolted together.
055 - 2. It should be 0.002 or 0.003 inch below the surrounding surface.
055 - 3. Because sufficient room must be provided beneath the lock-ring to allow for the burrs that it creates when it is installed in the parent metal.
055 - 4. A bolt and a nut.
055 - 5. Because the locking device is difficult to remove without damaging the parent threads.
055 - 6. The neck of the insert must be drilled so that the insert is separated from the lock-ring. Then the lock-ring should be pryed out and the insert removed with an extractor.
055 - 7. Because if the parent threads become so damaged that they cannot be reused, then the part must usually be replaced. (Because of the amount of space involved, a damaged solid insert seat can seldom be taken out to the next, size.)

056 - 1. A Heli-Coil tap, an inserting tool, and a tang breakoff tool.
056 - 2. The Heli-Coil tap.
056 - 3. A drive pin punch and hammer.
056 - 4. By hand pressure, *not* by tapping on it with a hammer.
056 - 5. Remove any high metal or burrs that might be obstructing the top coil.
056 - 6. The parent threads can be stripped out.

AU GAFS AL(831619)900

STOP -

1. **MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.**

2. **USE NUMBER 2 PENCIL ONLY.**

53150 01 25

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
MACHINE SHOP FUNDAMENTALS

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if a all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DONT'S:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed.* Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

Note to Student. Consider all choices carefully and select the best answer to each question.

1. (001) In the Air Force Specialty Code 531X0, what do the numbers 531 represent?

   a. The metalworking career field.
   b. The machinist subdivision.
   c. The skill level.
   d. Both options b and c above.

2. (001) The 'X' in 531X0 is used when referring to

   a. a machinist before he or she acquires a 3 skill level.
   b. an Airman in training to a higher skill level.
   c. all the subdivisions within the metalworking career field.
   d. all the skill levels within the AFSC.

3. (001) The last number '0' in 531X0 is used in conjunction with the other numbers to identify

   a. the machinist specialty.
   b. an unskilled metalworking apprentice.
   c. an unskilled apprentice machinist.
   d. all the subdivisions within the metalworking career field.

4. (002) A basic airman may progress to the 3 skill level (apprentice machinist) by successfully completing a formal technical training course, by passing a By-Pass Specialist Test, or by

   a. serving in a position that requires a 3 skill level.
   b. serving as a metalworking apprentice for 90 days.
   c. being promoted to the grade of E-2.
   d. completing an OJT program at an assigned duty station.

5. (002) Which skill level is attained solely by OJT and does not have a specific rank requirement?

   a. 3
   b. 5
   c. 7
   d. 9

6. (002) An Airman is entered into an OJT program to train for the 7 skill level after reaching which rank?

   a. Technical Sergeant (E-6).
   b. Staff Sergeant (E-5).
   c. Sergeant (E-4).
   d. Senior Airman (E-3).

7. (002) Before a Master Sergeant can be awarded a 9 skill level, he or she must achieve a passing score on the USAF Supervisory Examination, and

   a. serve 6 month in a 9-level position.
   b. be selected for promotion to E-8.
   c. serve 6 months in a 9-level position and be selected for promotion to E-8.
   d. serve 6 months in a 9-level position or be selected for promotion to E-8.

8. (003) One of the biggest responsibilities of an apprentice machinist is to

   a. take a passive interest in training.
   b. take pride in every assigned task.
   c. assign work to other machinists.
   d. complete his or her training in the minimum allowable time.

9. (003) Which of the following statements best describes the way that a skilled machinist is expected to perform his or her assigned duties?

   a. Performs satisfactorily with a minimum of supervision.
   b. Performs proficiently with direct supervision.
   c. Performs satisfactorily only with supervisory aid.
   d. Performs proficiently with little or no supervision.

10. (003) Which of the following is not one of the basic areas of responsibility of a 5 skill level machinist?

   a. To supervise machine shop personnel.
   b. To assemble and fit machined parts.
   c. To manufacture and rework machined parts.
   d. To requisition new materials and equipment.

11. (004) Which of the following statements is the most accurate concerning the basic duties and responsibilities of the machine shop technician or the metalworking superintendent?

   a. The machine shop technician directs metalworking activities.
   b. The machine shop technician makes in-progress inspections during machining operations.
   c. The metalworking superintendent makes in-progress inspections during machining operations.
   d. The metalworking superintendent supervises machine shop personnel.

12. (004) Supervising the design and fabrication of precision tools is a responsibility most closely associated with

   a. a machine shop technician.
   b. a metalworking superintendent.
   c. a skilled machinist.
   d. both a and b.

13. (004) Which of the following statements most accurately describes the duties of the metalworking superintendent?

   a. To assign priority work within the shop.
   b. To intruct in setup procedures for shop machines.
   c. To supervise machine shop personnel.
   d. To coordinate the efforts of various shops.

14. (005) 'Of possible intelligence value' means that

   a. the information is classified; but, together with other bits of unclassified information could give an insight into classified plans.
   b. the information is unclassified; but, together with other bits of unclassified information could give an insight into classified plans.
   c. the information is classified; the disclosure of which could be embarassing to the Air Force.
   d. the information is unclassified and is not subject to control for any other reasons.

15. (006) Information that could be expected to cause damage to the defense interests of the nation if illegally disclosed would be

   a. classified - Confidential.
   b. classified - Top Secret.
   c. unclassified - Confidential.
   d. classified - Secret.

16. (006) Information that could result in serious damage to the nation if wrongfully disclosed would be

a. classified - Confidential.
b. unclassified - Confidential.
c. classified - Top Secret.
d. classified - Secret.

17. (006) Which of the following statements would best describe information that has been labeled 'For Official Use Only'?

a. Classified information which could cause serious damage to the nation if disclosed.
b. Classified information that isn't very important.
c. Unclassified information which can be released to the public without any controls.
d. Unclassified information that must be withheld from widespread public distribution.

18. (007) Secret information may be safely transmitted or sent by

a. both options c and d below.
b. telephone.
c. radio.
d. registered mail.

19. (008) The combining of the various security programs into one overall program is known as

a. OPSEC, Operations, Plans, and Security.
b. OSP, Operational Security Program.
c. OPS, Operations, Plans, and Security.
d. OPSEC, Operations Security.

20. (008) 'Talking around' refers to an attempt by personnel to

a. disguise their subject with homemade codes.
b. disguise their subject with official codes and ciphers.
c. discuss sensitive information in several different places.
d. discuss sensitive information by implying their meaning rather than actually saying it.

21. (008) The use of homemade codes when discussing sensitive information

a. is an effective form of security.
b. is acceptable under most conditions.
c. usually keeps unauthorized listeners from getting the message.
d. causes confusion for the intended recipient.

22. (010) The color of the supply condition tag that identifies an item as being condemned is

a. yellow.
b. red.
c. buff.
d. green.

23. (010) The DD Form 1574, Serviceable Tag - Material, is good for

a. serviceable, usable items that are new, used, or repaired.
b. serviceable items that have parts missing.
c. only on items that have been repaired in base shops.
d. only new items coming from supply.

24. (010) The DD Form 1577-2 (green tag) is used on

a. serviceable items that are ready for use.
b. unserviceable, condemned items.
c. all reparable items that would require more than 75% of their value to repair.
d. reparable items that can be repaired.

25. (010) The DD Form 1577 is used on

a. all items the repair of which would cost more than 75% of their value to repair.
b. items that cannot be repaired.
c. serviceable items with parts missing.
d. items that can be repaired at Depot level.

26. (011) How many digits comprise the National Stock Number (NSN)?

a. 14
b. 13
c. 11
d. 7

27. (011) Which supply volume contains a listing of USAF stocklists, DOD Federal Catalogs, and related cataloging publications?

a. H2-1, Cataloging Handbook.
b. H2-2, Cataloging Handbook.
c. C-RL-1, Cross Reference Index.
d. S-2A-1, Index.

28. (011) Which supply volume or list contains illustrations of some of the various type items listed within it?

a. H2-1, Cataloging Handbook.
b. C-RL-1, Cross Reference.
c. IL (Identification List).
d. ML (Management Data List).

29. (011) The AF Form 601b, Custodian Request/Receipt, is normally used to request the issue

a. or turn in of expendable items such as drill bits.
b. or turn in of nonexpendable items such as shop machinery.
c. or turn in of all material and supplies.
d. of items that do not have an assigned NSN.

30. (011) The Custodian Authorization/Custody Receipt Listing (CA/CRL) is a shop document that must normally be considered when submitting

a. an AF Form 601b.
b. an AF Form 2005.
c. DD Form 1348.
d. none of the above.

31. (011) AF Form 2005, Issue and Turn-in Request, is normally used for requesting the issue

a. of nonexpendable, non-stocklisted items.
b. of non-stocklisted items.
c. or turn in of nonexpendable items.
d. of expendable items.

32. (013) Why should the shop property custodian be particularly concerned about the property listed on the Custodian Authorization/Custody Receipt Listing (CA/CRL).

a. Because the property custodian is held accountable for all the property listed on the CA/CRL.
b. Because the property custodian is bucking for promotion.
c. Because the property custodian is held accountable for all the property in the shop.
d. Because the property custodian is held accountable for at least one-half the property on CA/CRL.

33. (014) For responsibility relief, which of the following forms will normally be completed when liability for property has been admitted and the total loss or damage does not exceed $250?

a. DD Form 1131, Cash Collection Voucher, or DD Form 362, Statement of Charges.
b. DD Form 1131, Cash Collection Voucher, or DD Form 200, Report of Survey.
c. DD Form 362, Statement of Charges, or DD Form 200, Report of Survey.
d. DD Form 200, Report of Survey with DD Form 1131, Cash Collection Voucher.

34. (014) DD Form 362, Statement of Charges, is used in lieu of DD Form 1131, Cash Collection Voucher, when the

a. individual admits pecuniary liability.
b. liable individual elects to pay cash.
c. damage or loss exceeds $250.
d. liable individual cannot pay cash.

35. (015) DD Form 200, Report of Survey, is used to obtain reimbursement for lost or damaged property when

a. it is necessary to drop an item of property from the records.
b. Each of the above conditions exists.
c. the loss or damage exceeds $250.
d. it is necessary to resolve questions of responsibility for loss and to fix liability.

36. (015) A Report of Survey, DD Form 200, must be initiated within how many days of the day the loss or damage was discovered?

a. 5 days
b. 10 days
c. 30 days
d. 45 days

37. (015) A Report of Survey (DD Form 200) must be filled out when

a. damage is $100.00 and the individual admits liability.
b. there is an accident of any kind.
c. any damage to Air Force property is involved.
d. damage is $300.00 and the individual does not admit liability.

38. (015) Sergeant Alpha discovered that a portable hoist had been listed on the CA/CRL for years even though the item had never been in the shop to anyone's knowledge. What form must be used to drop the item from the CA/CRL?

a. DD Form 200, Report of Survey.
b. DD Form 362, Statement of Charges.
c. DD Form 1131, Cash Collection Voucher.
d. Both options a and b.

39. (016) Which of the following should not be worn while working with or around shop machinery?

a. Wedding band.
b. Bracelet.
c. Dog tags.
d. All of the above.

40. (017) What is the minimum no-smoking distance around a building in which bulk oil is stored?

a. 25 feet.
b. 30 feet.
c. 50 feet.
d. 75 feet.

41. (017) Other than a CBM extinguisher, the best type of fire extinguisher for electrical fires is

a. dry chemical.
b. water.
c. dry sand.
d. carbon dioxide.

42. (018) The minimum safe distance in front of an operating jet engine is

a. 25 feet.
b. 25 yards.
c. 10 yards.
d. 10 feet.

43. (018) The air pressure in the lines of an air-driven tool should not exceed a maximum of

a. 75 psi.
b. 150 psi.
c. 200 psi.
d. 225 psi.

44. (020) Which of the following statements best describes the relationship between blueprints and mechanical drawings?

a. Blueprints are copies of mechanical drawings.
b. Blueprints are smaller than mechanical drawings.
c. Blueprints are larger than mechanical drawings.
d. Blueprints are on blue paper and mechanical drawings are on brown paper.

45. (020) The type of Technical Order drawing which is accompanied by a parts list which includes parts numbers and other useful information is

a. a working drawing.
b. a unit assembly drawing.
c. an exploded drawing.
d. a maintenance assembly drawing.

46. (021) In orthographic projection, the principle view should be used as the

a. top view, regardless of the natural top of the object.
b. end view, since it is not dimensional.
c. front view, regardless of the natural front of the object.
d. side view whenever possible.

47. (022) What line on a blueprint is used to indicate a part to which a note applies?

a. Phantom.
b. Extension.
c. Datum.
d. Leader.

BEST COPY AVAILABLE

48. (022) On mechanical drawings what lines indicate the alternate positions of parts of an object?

a. Break.
b. Sectioning.
c. Phantom.
d. Hidden.

49. (023) Which view on a blueprint is used to show the true outline of a slanted surface?

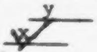
a. Sectional.
b. Front.
c. Auxiliary.
d. Extra.

50. (023) In sectional views, the crosshatching indicates the area that has been 'cut' by the cutting plane, and it normally indicates the

a. slant of the cutting plane.
b. direction of the cut.
c. type of material of the object.
d. direction of the cutting plane.

51. (023) Which sectional view intentionally shows a part of an object out of its true position to enhance clarity?

a. Partial.
b. Aligned.
c. Offset.
d. Revolved.

52. (024) In the surface finish symbol 

, what information would normally be given in the designated positions?

a. 'X' represents surface roughness; 'Y' represents the surface waviness.
b. 'X' represents degree of smoothness; 'Y' represents the type of operation.
c. 'X' represents type of operation; 'Y' represents the degree of smoothness.
d. 'X' represents surface waviness; 'Y' represents the surface roughness.

53. (025) In the metric system, how many millimeters are equal to one inch?

a. 25.4.
b. 24.5.
c. 5.4.
d. .039.

54. (025) To convert 35.2 millimeters to inches, you would

a. multiply 35.2 by 0.03937.
b. divide 35.2 by 0.03937.
c. multiply 35.2 by 25.4.
d. divide 35.2 by 24.5.

55. (026) To make the initial sketch of a large circle, you should

a. rotate the paper and draw a heavy line using your wrist as a pivot point.
b. rotate the paper with your second finger, as the pivot point, resting on the center of the proposed circle.
c. hold the paper stationary and use your wrist as the pivot point.
d. hold the paper stationary and draw a heavy line using your wrist as the pivot point.

56. (027) What should the included angle of a center punch be?

a. 60 degrees.
b. 90 degrees.
c. 100 degrees.
d. 118 degrees.

57. (027) The included angle of a chisel cutting edge should be

a. from 60 degrees for cutting softer materials to 70 degrees for harder materials.
b. from 60 degrees for cutting harder materials to 70 degrees for softer materials.
c. from 50 degrees for cutting softer materials to 70 degrees for harder materials.
d. from 50 degrees for cutting harder materials to 70 degrees for softer materials.

58. (028) Using a screwdriver that is too small for the slot of the screw could most likely result in

a. damage to the area around the screw.
b. damage to the screwdriver tip.
c. damage to the screw head.
d. damage as indicated in options b and c above.

59. (028) What grinding operation is sometimes necessary on the jaws of a pair of common pliers?

a. Regrinding the tops of the jaws.
b. Grinding the jaws to the same length.
c. Regrinding the jaw teeth.
d. Rounding the sharp corners.

60. (028) Which of the following wrenches should not be used to loosen a nut?

a. Torque.
b. Adjustable.
c. Open end.
d. Box-end.

61. (029) To properly cut through a 2-inch brass rod with a hacksaw, you should use

a. an all hard blade.
b. a 32 pitch blade.
c. a flexible blade.
d. a 34 pitch blade.

62. (030) The 'cut' of a file refers to

a. the coarseness (bastard, smooth, etc).
b. the width of the cutting surface.
c. the type of cut (single or double).
d. both options a and c above.

63. (030) When metal chips become lodged in the teeth of a file, the condition is known as

a. lodging.
b. clogging.
c. binding.
d. pinning.

64. (030) Which of the following types of scrapers should be used to scrape the angular portion of a dovetail bearing surface?

a. Hooked scraper.
b. Half-round bent scraper.
c. Half-round scraper.
d. Three-cornered scraper.

65. (031) In addition to checking for squareness, the square head and blade of the combination set can be used to

a. check 45 degree angles.
b. check 60 degree angles.
c. quickly locate the center of round stock.
d. do all of the above.

66. (032) One of the most important points to remember when using a pneumatic handtool is to regulate the

a. air pressure to 150 psi or less.
b. air pressure to at least 150 psi.
c. pressure only on flight line jobs.
d. pressure at the handtool and not in the air line.

67. (032) The life of pneumatic handtools can be prolonged most effectively by

a. periodically putting a few drops of oil into the air intake fitting.
b. using them only on the flight line.
c. using them only in maintenance shops.
d. periodically washing them in clear water and allowing them to air dry.

68. (033) Each graduation on the thimble of an outside micrometer represents

a. 0.0001 inch.
b. 1/40 inch.
c. 0.001 inch.
d. 1/25 inch.

69. (033) Before moving the spindle of a 1-inch micrometer into contact with the anvil in checking for accuracy, you should

a. clean the anvil and spindle contact surfaces.
b. turn the barrel slowly until contact is made.
c. remove the thimble.
d. insert a 1-inch gage block between the spindle and the anvil.

70. (034) To obtain an accurate measurement, it is important that a small hole gage be properly aligned in a micrometer because

a. the surface of the gage is not a true circle.
b. misalignment will damage the micrometer.
c. misalignment will damage the gage.
d. of both options b and c above.

71. (035) To obtain the correct diameter of a hole using an inside micrometer, what must be added to the actual micrometer reading?

a. The length of the extension rod.
b. The length of the micrometer body.
c. The length of the micrometer thimble.
d. The length of the body and the extension rod.

72. (036) Each graduation on the main scale of a vernier caliper or height gage will equal

a. 0.001 inch.
b. 0.015 inch.
c. 0.025 inch.
d. 0.040 inch.

73. (036) On most vernier height gages, when the sliding arm is set at its lowest measurement, the gaging surface is

a. one inch from the bottom of the base.
b. one inch from the top of the base.
c. one inch plus the thickness of the arm from the bottom of the base.
d. the thickness of the arm from the bottom of the base.

74. (036) The vernier bevel protractor accurately divides a degree into segments of

a. 5 seconds each.
b. 5 minutes each.
c. 10 minutes each.
d. 25 minutes each.

75. (037) To check for curvature in a shaft with a dial indicator, mount the ends of the shaft in V-blocks and then take

a. two indicator readings around the shaft 180 degrees apart.
b. three indicator readings around the shaft 90 degrees apart.
c. four indicator readings around the shaft 90 degrees apart.
d. four indicator readings around the shaft 60 degrees apart.

76. (037) When you center a part on a lathe faceplate with a dial indicator, you should

a. tap lightly on the work while the indicator is engaged.
b. disengage the indicator and then tap work in the required distance.
c. tap lightly on the indicator until the required reading is obtained.
d. tap the work sharply while the indicator is engaged.

77. (039) The fact that precision gage blocks will adhere to each other when properly wrung together is the result of

a. a slight magnetism in each of the gage blocks in the set.
b. the heavy pressure applied during the 'wringing' process.
c. the extreme accuracy maintained during their manufacture.
d. a light oil film impregnated into the gage blocks.

78. (040) What is the height of gage blocks required to set a 10-inch sine bar at an angle of 48 degrees 15 minutes (the sine of the angle is 0.74606)?

a. 7.4604 inch.
b. 0.7500 inch.
c. 0.07460 inch.
d. 0.007460 inch.

79. (040) To find the height of the gage block to set a 5-inch sine bar to a given angle, you would

a. multiply the sine of the angle by 5.
b. multiply the angle by 5.
c. multiply the cosine of the angle by 5.
d. divide the sine of the angle by 5.

80. (040) A light oil film should be applied to sine bar sets

a. prior to use.
b. when it will be necessary to handle them with bare hands.
c. after the set has been stored for a week or more.
d. prior to storing for extended periods.

81. (041) To use toolmaker's buttons to accurately locate a series of holes, you should

a. not drill any holes before mounting the buttons.
b. drill and tap holes in the appropriate center locations.
c. drill an extra hole near an edge as a reference point.
d. drill all the holes by standard methods and use the buttons to check your accuracy.

82. (041) When you must check the center distance between two mounted toolmaker's buttons with an outside micrometer, you must

a. subtract 1/2 the diameter of both buttons from the micrometer reading.
b. add 1/2 the diameter of both buttons to the micrometer reading.
c. add the diameter of both buttons to the micrometer reading.
d. subtract the diameter of both buttons from the micrometer reading.

83. (041) After you have accurately mounted the toolmaker's buttons in the drilled and tapped holes, the next step is to

a. use an indicator on the button to properly locate the work for boring.
b. remove the button and drill the hole in a drill press.
c. bore a pilot hole using the button as a drill guide.
d. use a hammer to tap the button into position in the drill press.

84. (042) In layout work, parellels, V-blocks, and angle plates are used mostly to

a. support round stock in a fixed position.
b. support objects at 90 degree angles to the surface plate.
c. support work in a particular position or location.
d. check the accuracy of precision measuring tools.

85. (042) When you use a surface gage to scribe layout lines, you should not

a. scribe horizontal lines with the curved end of the scriber.
b. scribe heavy, deep lines unless layout compound is thin.
c. scribe horizontal lines with the straight end of the scriber.
d. go back and forth over the scribed lines.

86. (043) On a stud that is marked as being 0.006 inch oversize, the part of the thread that is actually 0.006 inch bigger than the standard stud is

a. the pitch diameter.
b. the major diameter.
c. the minor diameter.
d. both options a and c above.

87. (043) When a plain stepped stud (not flanged) is secured with a dowel or lockpin, the pin interrupts

a. only the threads in the parent part.
b. both the threads on the stud and in the parent metal.
c. neither the threads on the stud nor in the parent part.
d. only the threads on the stud.

88. (043) A type of stud that is secured by a lockpin that does not interrupt any threads is a

a. flanged stepped stud.
b. straight stud.
c. necked stepped stud.
d. lockring stepped stud.

89. (044) A simple but many times effective method of removing a damaged stud is to use

a. a punch and hammer.
b. self-locking pliers.
c. a scribe.
d. all of the above.

90. (045) The width of the spline face in a splined stud removal tool should be

a. from 1/32 inch for smaller studs to 1/16 inch for larger ones.
b. either 1/32 inch or 1/16 inch, depending on stud size.
c. from 1/32 inch for larger studs to 1/16 inch for smaller ones.
d. 1/32 inch for fine threads and 1/16 inch for coarse threads.

91. (045) A splined stud removal tool is to be made. The circumference of the center hole was computed to be 1.373 inch. The sum of the diameter of the spline hole drill plus the desired width of face is 0.171 inch. How many holes should be drilled?

a. 6
b. 9
c. 7
d. 8

92. (046) When a stud is prepared for an Ezy-Out or tool bit type stud extractor, the hole should be

a. drilled no more than half way through the stud.
b. drilled with the tap drill for the stud.
c. drilled as close to the stud center as possible.
d. no bigger than the small end of the extractor.

93. (046) Before you use a stud extractor to remove a damaged stud, you should

a. grind the Ezy-Out to fit the hole in the stud.
b. drill through the entire length of the stud.
c. drill through the stud with the tap drill.
d. drill deep enough to accept 1/4 inch of the extractor.

94. (047) To assure that the parent threads are not damaged when removing a stud by drilling, normally the best size final drill to use is

a. the tap drill.
b. one size smaller than the tap drill.
c. one size smaller than the body drill.
d. one size larger than the tap drill.

95. (047) A form of drilling in which the parent threads around a damaged stud are completely destroyed is called

a. pinning.
b. tap drilling.
c. trepanning.
d. extractor drilling.

96. (048) Before you replace a stud on an aircraft or its associated equipment, you should

a. polish the stud threads with an emery cloth.
b. check the applicable technical order for the proper replacement size.
c. fill the threaded hole with oil to make insert of the stud easier.
d. run a die over the stud threads so they will fit the hole.

BEST COPY AVAILABLE

97. (048) If you are drilling a lockpin hole for a stud and the drill bit breaks, you should then

a. remove the stud and then pick the broken bit out.
b. remove the broken bit and install the lockpin.
c. leave the bit in place until the stud is damaged again.
d. leave the bit in place as a substitute pin.

98. (048) Two nuts may be used as an expedient stud driver, but they can damage the thread strain if

a. the stud becomes very tight during installation.
b. they are locked together too tightly.
c. they slip while locked tightly together.
d. all of the above conditions exist.

99. (048) To make a good stud driver from a piece of hex stock and a bolt, it should be long enough to accept at least

a. 1/2 the total stud length.
b. 1/2 inch of the stud threads.
c. 1/4 inch of the stud threads.
d. 3/8 inch of the stud thread length.

100. (049) To remove a broken spark plug, it would be logical to try a stud extractor first because

a. the hole for the extractor is already in the plug base.
b. the plug base can be easily drilled for an extractor.
c. the plug will usually come out with an extractor.
d. it is the only way the plug can be removed.

101. (049) To remove a broken spark plug using the drill jig method, how many holes should be drilled in the wall of the plug base?

a. 2
b. 3
c. 4
d. 5

102. (050) A way to increase the effectiveness of a speed handle for removing screws so they will be undamaged, is to

a. increase its length by several inches.
b. make a pressure pad for the handle.
c. shorten its length by several inches.
d. shorten the handle only.

103. (051) A pneumatic hammer can be used to loosen only those screws that

a. are set in solidly supported panels or surfaces.
b. have been completely stripped out.
c. cannot be drilled out.
d. are in unsupported panels or surfaces.

104. (051) When you use the pneumatic hammer and adapter to remove screws, you should rotate the screw

a. no more than 1/4 turn with the hammer.
b. no more than a 3/4 turn with the hammer.
c. approximately three (3) full turns with the hammer.
d. completely out with the hammer.

105. (051) A screw should not be rotated more than 1/4 inch with the pneumatic hammer and adapter because

a. it will probably cause damage the parent threads.
b. it can damage the hammer.
c. the adapter can be broken by rotating the screw farther.
d. the adapter will not turn more than that.

106. (052) To make a screw punch from a 3/8 tool bit and hex stock, the diameter of the hole in the handle should be slightly

a. larger than distance across the flats of the tool bit.
b. smaller than the distance across the flats of the tool bit.
c. larger than the distance across the corners of the tool bit.
d. smaller than the distance across the corners of the tool bit.

107. (052) The end surface of the tool bit in a screw punch should slope back from the cutting edge (bottom edge) at an angle of approximately

a. 2 degrees.
b. 10 degrees.
c. 30 degrees.
d. 45 degrees.

108. (053) A method of screw removal that involves drilling and is best used when an entire panel contains several damaged screws is to

a. use a drill equal to the major diameter of the screw.
b. tap drill the screw.
c. drill for extractors.
d. drill off the screw heads.

109. (053) You intend to remove a screw from a nut-plate with an extractor. Since the head of the screw has been removed, you should use only moderate hand pressure instead of a hammer to seat the extractor because

a. a hammer is not necessary to remove the screw.
b. more pressure will break the wall of the screw.
c. the use a hammer can tear the nut-plate loose.
d. using a hammer can damage the screw.

110. (053) When you remove a screw from a nut-plate by drilling it out, it is difficult to keep the drill in the center of the screw because

a. screws in nut-plates are extra hard.
b. nut-plates 'float' or move around in their bracket.
c. drill bits dull quickly when drilling around nut-plates.
d. nut-plates are only used in hard-to-get-at places.

111. (054) Solid inserts include all the following except for

a. inserts secured with lockpins.
b. lock-ring inserts.
c. Heli-Coil inserts.
d. flanged inserts.

112. (054) On new equipment, Heli-Coils will do all of the following except to

a. help prevent thread failure.
b. reduce maintenance cost.
c. effectively seal off liquid pressure.
d. permit the use of thinner flanges.

113. (055) When you install a flanged insert, it is usually best to have the top surface of the flange

a. slightly below the parent surface.
b. just below the first parent thread.
c. flush with the parent surface.
d. slightly above the parent surface.

114. (055) To prepare the seat for inserts with serrated lock-rings, the counterbore should be slightly deeper than the thickness of the lock-ring so that

a. a clearance is provided for burrs produced by the ring.
b. the insert will extend above the ring.
c. a clearance is provided for burrs produced by the insert.
d. a clearance is provided for burrs produced by the tap.

115. (055) To remove an insert that is secured with a serrated lock-ring, you should normally pry the ring out after

a. removing the insert.
b. drilling serrations on the outside of the ring.
c. drilling the neck of the insert out.
d. drilling out the lock-pin.

116. (056) A Heli-Coil should be installed so that the top coil is approximately

a. 1/2 turn below the parent surface.
b. two turns below the parent surface.
c. slightly above the parent surface.
d. flush with the parent surface.

117. (056) In case a standard tang break-off tool is not available, what should be used as a substitute?

a. Self-locking pliers.
b. A standard tap.
c. The inserting tool.
d. A drive pin punch.

118. (056) To properly seat a Heli-Coil removal tool, you should use

a. a series of light taps with a hammer.
b. hand pressure only.
c. only light hammer blows.
d. several hard blows with a hammer.

119. (056) A damaged Heli-Coil should never be pulled straight out of the parent threads because

a. the parent threads will be damaged.
b. the Heli-Coil will be damaged.
c. the puller can be damaged.
d. of all of the above reasons.

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 44 USC 3101. PRINCIPAL PURPOSE(S): To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with every ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA: MAIL TO ECI GUNTER AFS ALA 36118

1. THIS REQUEST CONCERNS COURSE
2. TODAY'S DATE
3. ENROLLMENT DATE
4. PREVIOUS SERIAL NUMBER
5. SOCIAL SECURITY NUMBER ☐☐☐–☐☐–☐☐☐☐
6. GRADE/RANK
7. INITIALS ☐☐ LAST NAME
8. OTHER ECI COURSES NOW ENROLLED IN
9. ADDRESS: (OJT ENROLLEES - ADDRESS OF UNIT TRAINING OFFICE/ALL OTHERS - CURRENT MAILING ADDRESS)

ZIP CODE ☐☐☐☐☐

10. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE:
11. AUTOVON NUMBER
12. TEST CONTROL OFFICE ZIP CODE/SHRED

SECTION II: Old or INCORRECT ENROLLMENT DATA

1. NAME:
2. GRADE/RANK:
3. SSAN:
4. ADDRESS:
5. TEST OFFICE ZIP/SHRED:

SECTION III: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an "X" through number in box to left of service requested)

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. The latest course workbooks have a Form 17 printed on the last page.

1 EXTEND COURSE COMPLETION DATE. (Justify in Remarks)

2 SEND VRE ANSWER SHEETS FOR VOL(s): 1 2 3 4 5 6 7 8 9 - ORIGINALS WERE: NOT RECEIVED, LOST, MISUSED

3 SEND COURSE MATERIALS (Specify in remarks) - ORIGINALS WERE: NOT RECEIVED, LOST, DAMAGED.

4 COURSE EXAM NOT YET RECEIVED. FINAL VRE SUBMITTED FOR GRADING ON (Date):

5 RESULTS FOR VRE VOL(s): 1 2 3 4 5 6 7 8 9 NOT YET RECEIVED. ANSWER SHEET(s) SUBMITTED ON (Date):

6 RESULTS FOR CE NOT YET RECEIVED. ANSWER SHEET SUBMITTED TO ECI ON (Date):

7 PREVIOUS INQUIRY (ECI FORM 17, LTR, MSG) SENT TO ECI ON:

8 GIVE INSTRUCTIONAL ASSISTANCE AS REQUESTED ON REVERSE:

9 OTHER (Explain fully in remarks)

REMARKS: (Continue on Reverse)

OJT STUDENTS must have their OJT Administrator certify this request.

ALL OTHER STUDENTS may certify their own requests.

I certify that the information on this form is accurate and that this request cannot be answered at this station. (Signature)

ECI FORM JUN 77 17 PREVIOUS EDITIONS MAY BE USED

BEST COPY AVAILABLE

SECTION IV: REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of textual material should be forwarded directly to preparing agency. Name of agency can be found at the bottom of the inside cover of each text. All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:

MY QUESTION IS:

Course No. ___________

Volume No. ___________

VRE Form No. _________

VRE Item No. _________

Answer You Chose
(Letter) ___________

Has VRE Answer Sheet
been submitted for grading?

☐ YES ☐ NO

REFERENCE
(Textual support for the answer I chose can be found as shown below)

In Volume No: _________

On Page No: ___________

In______ (Left)_____(Right)
Column

Lines____Through______

Remarks:

53150 02 7702

CDC 53150

MACHINIST

(AFSC 53150)

Volume 2

Metallurgy and Advanced Machine Work

Proficimus More Irretenti

Extension Course Institute

Air University

Prepared by
MSgt Teddy L. Ford
3340 Technical Training Group
USAF School of Applied Aerospace Sciences (ATC)
Chanute AFB, Illinois 61868

Reviewed by
John K. Waller, Education Specialist
Extension Course Institute (AU)
Gunter AFS, Alabama 36118

PREPARED BY
3340 TECHNICAL TRAINING GROUP
USAF SCHOOL OF APPLIED AEROSPACE SCIENCES (ATC)
CHANUTE AIR FORCE BASE, ILLINOIS

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS SECOND volume of CDC 53150, *Machinist*, covers metallurgy and advanced machine work. Chapter 1 is a brief study of the characteristics and uses of metals. You will need this information in almost every aspect of your job as a machinist. As you work with metals and machines, you will also quickly recognize the need for machine lubricants, cutting fluids, and coolants. That is what Chapter 2 is all about. Chapter 3 begins our study of the various machines that you will operate, beginning with power cutoff machines. Chapter 4 deals with drill presses, and Chapter 5 covers lathes.

Code numbers appearing on figures are for preparing agency identification only.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOXC, Chanute AFB IL 61868. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of July 1976.

Acknowledgment

THE ITEM listed below has been reproduced by permission of the following:

Figure 3-2	Johnson Manufacturing Corporation, Albian, Michigan 49224

Contents

Page

Preface ... iii

Acknowledgment ... iv

Chapter

1 Metallurgy ... 1

2 Lubricants and Coolants ... 17

3 Power Cutoff and Contour Machines ... 25

4 Drill Press Work ... 50

5 Lathe Work ... 64

Bibliography ... 104

Answers for Exercises ... 105

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Metallurgy

AS A MACHINIST you work every day with a variety of metals. You manufacture new tools and parts from different kinds of metals, and you repair worn or broken metal parts. These operations would fail if you did not have at least a general knowledge of how various metals are identified and marked, what are their characteristics, how they are used, how they are affected by heat treatment, and how they can be tested for hardness. Therefore we discuss those points in this chapter.

1-1. Identification of Metals

Before we can effectively learn the characteristics and uses of various metals, we must learn how they are classified, how the different types are coded for identification, and how metal stock should be marked so that each kind will be easily distinguished. In the following three objectives, we will discuss each of these areas briefly before beginning our next section on the characteristics and uses of metals.

200. Define the meaning of the "ferrous" and "nonferrous" classifications, and identify metals within each.

Metals Classification. All metals may be classified as *ferrous* or *nonferrous*. A ferrous metal is any metal that has iron as its main element. A metal is still considered ferrous even if it contains less than 50 percent iron, as long as it contains more iron than any other one metal. A metal is considered nonferrous if it contains less iron than any other metal.

Ferrous metals include cast iron, steel, and the various steel alloys. The only difference between cast iron and steel is in the amount of carbon. Cast iron contains more than 2 percent carbon, while steel contains less than 2 percent. An alloy is a substance composed of two or more elements. Therefore all steels are an alloy of iron and carbon, but the term "alloy steel" normally refers to a steel that also contains one or more other elements. For example, if the main alloying element is tungsten, the steel is a "tungsten steel" or a "tungsten alloy." If there is no alloying material, it is a "carbon steel."

Alloy steels have been developed to meet the needs of modern industry for tougher, stronger, and harder steels than can be obtained in simple carbon steels. Alloys, such as nickel, chromium, tungsten, vanadium, manganese, and molybdenum, all give distinct properties to the steel; but in all cases the principal advantages are the increase in hardness and toughness.

Nonferrous metals include a great many metals that are used mainly for metal plating or as alloying elements, such as tin, zinc, silver, and gold. We are primarily concerned with the metals used in the manufacture of parts, such as aluminum, magnesium, titanium, nickel, copper, and their alloys.

Exercises (200):

1. Define the term "ferrous."

2. Define the term "nonferrous."

3. Identify the following metals as "ferrous" or "nonferrous."
   a. Bronze.

   b. Copper.

   c. Gray cast iron.

   d. Chrome-molybdenum steels.

   e. Carbon steel.

f. Magnesium.

g. Brass.

4. What does the term "alloy steel" generally refer to?

201. Interpret the various numerical codes used to identify metals.

Numerical Codes. The terms "steel" and "aluminum" are general in meaning. There are many different types of steel and aluminum. They vary greatly in their chemical composition and physical properties because each piece of metal is manufactured to meet certain specifications. Since it is not possible to mark all of this data on each individual piece of metal, it is represented by a specification number.

Unfortunately there is no single unified numerical code for metals. Each manufacturer has its own code or specification number system. This is confusing, since there is no uniformity between manufacturers. In an attempt to correct this situation, several agencies of the metals industry and the Federal Government have developed specification number systems. As a result you may find any one of seven different specification code numbers stamped on a piece of metal or written on an identification tag. Five of the seven codes cover both ferrous and nonferrous metals. The Aluminum Association code is restricted to aluminum. The American Iron and Steel Institute code is restricted to ferrous metals.

SAE code. Perhaps the best known numerical code is the Society of Automotive Engineers (SAE) code. For the metals industry this organization pioneered in developing a uniform code based on chemical analysis. SAE specifications are rather broad and are not complete procurement specifications; however, they cover the basic industrial metals. SAE specification numbers are now used less widely than in the past; however, the SAE numerical code is the basic code for ferrous metals. It is especially useful in identifying metals, such as steels, by chemical composition. You will often hear machinists talk about "1020," "1095," or "4130" steel. These are SAE numbers. They have meaning, not so much as do particular specification numbers, but meaning in terms of carbon content (low, medium, or high) or in terms of nickel steel, chromium steel, etc. SAE specifications are nearly always restricted to chemical composition.

The SAE system is based on the use of four- or five-digit numbers. The *first* number indicates the type of steel; for example, 1 indicates a carbon steel, 2 nickel steel, etc. In the case of alloy steels, the *second* number—and sometimes the *third*—usually indicates the approximate percentage of the principal alloying element. The final *two* numbers—sometimes three—indicate the approximate carbon content in one-hundredth of 1 percent (0.01 percent). The SAE series numbers are given in figure 1-1. The following examples will help you understand this system:

SAE-1045
1 —— Type of steel (carbon)
0 —— Percent of alloy (none)
45 —— Carbon content (0.45 percent carbon)
SAE-2330
2 —— Type of steel (nickel)
3 —— Percent of alloy (3 percent nickel)
30 —— Carbon content (0.30 percent carbon)
SAE-71650
7 —— Type of steel (tungsten)
16 —— Percent of alloy (16 percent tungsten)
50 —— Carbon content (0.50 percent carbon)
SAE-50100
5 —— Type of steel (chromium)
0 —— Percent of alloy (less than 1 percent chromium
100 —— Carbon content (1 percent carbon)

AISI code. The American Iron and Steel Institute numerical code (AISI) is essentially the same as the SAE code. For example, SAE-1030 and AISI-C1030 are carbon steels of identical chemical composition. The two organizations have worked together in the past in expanding the SAE code to cover a greater number of specifications for ferrous metals. One difference between the two codes is that the prefix of an AISI number indicates the process used in the manufacture of the metal. The C in AISI-C1030 indicates that the steel is a basic open-hearth carbon steel.

AMS code. The Aeronautics Division of the SAE Standards Committee has developed the Aeronautical Material Specifications (AMS) code. These specifications are complete procurement specifications for materials used in the manufacture of aircraft, aircraft engines, propellers, and other aircraft accessories. The chemical and physical composition of AMS metals are coordinated as closely as possible with SAE general standards for similar metals. An example of an AMS number is AMS-5045B. The specification title for this number tells us that it is steel sheet and strip (low carbon, hard temper). AMS specification numbers indicate many detail requirements in addition to the chemical analysis of the material. Revised or amended specifications are indicated by letter suffixes; e.g., AMS-5045B is the second revision of AMS-5045.

ASTM code. The American Society for Testing Materials numerical code (ASTM) has much in common with the Aeronautical Materials Specification code. The ASTM specifications are

TYPE OF STEEL	SAE NUMBERS
Carbon Steels	1XXX
Plain Carbon	10XX
Free Cutting, Manganese	X13XX
Free Cutting, Screw Stock	11XX
High Manganese	T13XX
Nickel Steels	2XXX
.50% Nickel	20XX
1.50% Nickel	21XX
3.50% Nickel	23XX
5.00% Nickel	25XX
Nickel-Chromium Steels	3XXX
1.25% Nickel : .60% Chromium	31XX
1.75% Nickel : 1.00% Chromium	32XX
3.50% Nickel : 1.50% Chromium	33XX
3.00% Nickel : .80% Chromium	34XX
Corrosion and Heat Resisting	30XXX
Molybdenum Steels	4XXX
Chromium-Molybdenum	41XX
Chromium-Nickel-Molybdenum	43XX
Nickel Molybdenum	46XX & 48XX
Chromium Steels	5XXX
.60% to 1.10% Chromium	51XX
1.2% to 1.5% Chromium	52XXX
Corrosion and Heat Resistant	51XXX
Chromium-Vanadium Steels	6XXX
Tungsten Steels	7XXXX & 7XXX
Silicon-Manganese Steels	9XXX

53-126

Figure 1-1. SAE numerical code.

also complete procurement specifications and have many detailed meanings in addition to those of the chemical composition of the materials. For example, A5-55 is an ASTM specification number in which the A denotes ferrous material. The 5 in A5 is the serial number for high carbon steel joint bars, and the 55 following the dash indicates that the specification was adopted or last revised in 1955. A "T" suffix would indicate that the specification is tentative.

Federal Specification Numerical code. The Federal Specification Numerical code was developed to aid in the procurement of supplies used by the departments and independent agencies of the Federal Government. Each specification number is divided into three elements: (1) the group of materials or supplies to which the specification relates, (2) the initial letter of the title of the material, and (3) a serial number determined by the alphabetical location of the file. Two groups in this numerical code are QQ, Metals; and WW, Pipe, Pipe Fittings, Tubes, and Tubing (metallic). For example, the Federal Specification number of Steel, Corr. Res., Bars & Forgings (Except for Reforging) is QQ-S-763a (-1). The small letter suffix "a" indicates the first division of QQ-S-763. The number of amendments is indicated by the number in parentheses. The (-1) in the example given indicates that one amendment has been made to QQ-S-763a. Each division completely supersedes the earlier issues and all amendments thereto. Federal Specifications are complete procurement specifications and have many detail requirements in addition to the chemical analysis of the material.

MIL and JAN code. The Department of Defense has developed a numerical code which consists of two series: Military Specifications (MIL) and Joint Army-Navy Specifications (JAN). They can be used as procurement specifications and may have other details in addition to those that reveal chemical composition.

AA code. The Aluminum Association has developed a numerical code for wrought aluminum and aluminum alloy products. Specifications are very general; they are not complete procurement specifications. We will discuss the Aluminum Association numerical code here in some detail. We want to show the relationship between specification numbers and the chemical analysis and the physical properties of aluminum.

The Aluminum Association (AA) system of identification of aluminum consists of a four-digit number which indicates the type of alloy, the control over impurities, and the specific alloy. The first number indicates the type of alloy; for example, 2 is copper, 3 is manganese, 4 is silicon, etc. (See figure 1-2.) The second number indicates a specific control of impurities. If the second number is 0, it indicates that no control has been used.

In the case of commercially pure aluminum, the 1000 series, the last two digits of the identification number represent the amount of aluminum above 99 percent in one-hundredths of 1 percent. Thus, AA-1040 indicates a commercially pure aluminum containing at least 99.40 percent aluminum.

The last two digits in the 2000 to 8000 series have no particular significance other than to identify a commercially designated alloy composition within the series. When the AA system was initiated, the existing commercial designations were used as these last two digits; for example, 14S became 2014, 75S became 7075, etc. When a new alloy is developed, it is assigned the lowest unused number from 01 through 99. Thus, AA-2024 means:

2 ___ Type of alloy (copper)
0 ___ Control of impurities (none used)
24 ___ Manufacturers composition designation

Aluminum alloys varying greatly in hardness and physical condition or characteristics are available. We call these differences "temper." Letter symbols represent the different tempers. In addition to a letter, one or more numbers are sometimes used to indicate further differences. The temper designation is separated from the basic four-digit identification number by a dash; for example, 2024-T6. In this case we have an aluminum alloy, 2024, with a T6 temper (solution heat treated and then artificially aged).

We have discussed seven different numerical

MAJOR ALLOYING ELEMENT	
Aluminum at least 99% pure	1XXX
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and Silicon	6XXX
Zinc	7XXX
Other Elements	8XXX
Unused Series	9XXX

53—127

Figure 1-2. Aluminum alloy groups.

codes or specification number systems. The Department of Defense has developed a master code which ties all of these codes or systems together. It is explained in Military Handbook H1B, *Cross-Index of Chemically Equivalent Specifications and Identification Codes (Ferrous and Nonferrous Alloys)*. The master code groups materials of similar chemical composition which may be represented by one or more specifications. The five-digit code numbers cover both ferrous and nonferrous alloys but are not specification numbers and cannot be used to procure materials. This identification code is extremely valuable because it provides a reference for comparing the material composition of various specifications.

Exercises (201):

1. What does the number 95 mean in SAE number 1095?

2. Give the number meaning and breakdown for SAE number 4140.

3. Give the AISI number for 1040 open-hearth carbon steel.

4. What is the AMS code used for?

5. Give the third revised specification number for AMS-5095.

6. What identification codes are designed for the Department of Defense use?

7. Explain the metal designation of number AA-4024.

8. What type of aluminum is identified by AA number 1100 and what is the percentage of aluminum?

9. What is the basis for comparison of the different types of metals in the Military Handbook H1B?

202. Name and describe the various shop methods of marking metal for storage.

Proper identification of a metal is necessary if we are to insure that a locally manufactured item has the required properties. Unknown metals or metals that are not positively identified cannot be used. Various methods of identification and markings are used.

The most positive means of identification is by Military or Federal Specification Number. When metal is received in the shop, it is normally identified by a specification number, or by a Federal Stock Number that can be cross-referenced to a specification number. To insure that the metal remains properly identified, each piece must be marked in accordance with Technical Order 42D-1-3.

Methods of Marking. One of the three marking methods which are listed in Technical Order 42D-1-3 must be used to mark metal that has not been marked in accordance with Federal or Military Standards by the manufacturer. In order of preference, the three approved methods are (1) stencil and paint, (2) color code, and (3) stamping with metal dies.

Stenciling A stencil and white or black paint, whichever shows up better on the metal being marked, should be used when the size of the metal piece permits. The Federal or Military Specification Number should be stenciled on the metal in vertically and horizontally aligned rows. The distance between the vertical rows should not exceed 36 inches, and the distance between the horizontal rows should not exceed 10 inches.

Air Force color coding. Several significant changes have been made in Technical Order 42D-1-3 pertaining to color codes. Two additional colors, gold and silver, have been added to the 10 colors which are used to represent numerals and letters, figure 1-3. Aeronautical Material Specification and Military Specification metals of aircraft quality require an additional stripe that indicates the condition or quality of the metal. Gold is used to represent the letter N and indicates a normalized temper. Silver is used to represent the letter Q and indicates aircraft quality. The commercial designations, American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), and Aluminum Association (AA) numbers are used as the designation numbers. The stripes need not extend completely around the circumference of a rod or bar. Instead, dots may now be used, provided that the dots extend a third of the distance around the rod and that dots are used on two sides. The color code marking is no longer required in the center of the bar.

Stamping. Stamping the specification number into the metal is permitted only when it is impossible to use the stencil or color code methods. It is usually necessary to cut or eliminate the marked portion of the metal prior to using the material for work stock. Therefore the marking should be located where waste will be

COLOR	NUMBER	LETTER
BLUE	1	F
GREEN	2	H
OLIVE DRAB	3	O
YELLOW	4	T
ORANGE	5	W
RED	6	A
MAROON	7	B
WHITE	8	C
GRAY	9	D
BLACK	O	S
GOLD		N
SILVER		Q

53-128

Figure 1-3. Air Force color code.

held to a minimum. Gothic style numerals and letters should be used; the height may be 1/16 inch, 1/8 inch, or 1/4 inch, depending upon the size of the material being marked.

Now try a few more questions, and then we will begin a section on the characteristics and properties of metal.

Exercises (202):

1. List in order of preference the approved methods of marking metal.

2. If stenciling is used, what data should be stenciled on the metal?

3. What do the two newest additions (N and Q) to the color code indicate and what colors are used to depict them?

4. Why is stamping suggested for use only when it is impossible to use the color code or stencil methods?

1-2. Properties and Characteristics of Metals

It is important for you, as a machinist, to be able to determine what metal to use in a specific situation. To be able to do that, you will need a basic understanding of the mechanical properties and the characteristics of metal. In this section we will discuss these mechanical properties and characteristics.

203. Define the various mechanical properties of metal and state the relationships between them.

Mechanical Properties. The internal reactions of a metal to external forces are known as mechanical properties. The mechanical properties are directly related to each other. A change in one property usually causes a change in one or more additional properties. For example, if you increase the hardness of a metal, the brittleness usually increases and the toughness usually decreases. Following is a brief explanation of the mechanical properties and how they relate to each other.

Hardness. Hardness is the resistance a substance offers to deformation or penetration. The hardness of a metal can usually be controlled by heat treatment.

Tensile strength. Tensile strength is the resistance that a substance offers to being pulled apart by a slowly applied load. Tensile strength increases or decreases as the hardness increases or decreases. The tensile strength of metal is usually stated as pounds per square inch of cross-sectional area.

Brittleness. Brittleness is the tendency of a material to fracture or break with little or no deformation, bending, or twisting. Brittleness is usually not a desirable mechanical property. Normally, the harder the metal, the more brittle it is.

Shear strength. Shear strength is the resistance to an action similar to the cutting of a pair of scissors. A shear action is a force acting in a tangential manner which tends to cause the particles of a body to slide over each other. The shear strength of steel is approximately 60 percent of the tensile strength. Shear strength can be controlled in the same manner as tensile strength, i.e., by varying the hardness of the metal.

Ductility. Ductility is the ability of a substance to be elongated without breaking. Metals that are comparatively soft are usually ductile.

Toughness. Toughness is the ability of a material to absorb sudden shock without breaking. Usually, the harder the material, the less tough it is.

Wear resistance. Wear resistance is the ability of a substance to resist the cutting or abrasive action resulting from a sliding motion between two surfaces under pressure. A hard material usually has good wear resistance.

Stress. Stress is the reaction within a material to an externally applied force.

Strain. Strain, or deformation, is the change in the length per unit of length within a material subjected to a stress.

In our next two objectives we will cover some characteristics of various types of ferrous and nonferrous metals, but first, test your knowledge on these few questions.

Exercises (203):

1. What happens to the toughness of metal as the hardness is increased?

2. Explain tensile strength.

3. How can the shear strength of metal be controlled?

4. Define ductility.

5. What is the difference between stress and strain?

204. Name and describe the characteristics and uses of various types of ferrous metals.

Characteristics and Uses. Steel is manufactured to meet a wide variety of specifications for hardness, toughness, machinability, etc. Manufacturers use various alloying elements to obtain these characteristics. As a general rule, the more alloying elements added to steel, the poorer the machinability. Sulfur and phosphorus, however, are two elements used for the purpose of increasing machinability. The 1100 series carbon steels and type 303 corrosion-resistant (stainless) steel contain sulfur additives and are known as "free-machining" metals. However, machinability additives usually cause undesirable effects on other characteristics. For example, sulfur tends to decrease surface quality, weldability, and impact resistance. Figure 1-4 shows some of the general characteristics obtained by the use of various alloying elements. Following is a list of some common steels and their uses.

Carbon steels (SAE-1000 series) are usually classified as low, medium, or high carbon steels. They are usually brittle at subzero temperatures and should not be used under such conditions.

Low carbon steels (0.10 to 0.30 percent carbon), SAE-1010 to -1030, are generally used for ground installation parts, such as jigs, stands, and structures. They are sometimes used for aircraft parts which do not require much strength. They can be case hardened.

Medium carbon steels (0.30 to 0.50 percent carbon), SAE-1030 to -1050, are often used for bolts, pins, clevises, terminals, and shafting not intended for aircraft use. They are stronger than low carbon steels and can be hardened somewhat by heat treatment.

High carbon steels (0.50 to 1.05 percent carbon), SAE-1050 to -1095, are used for springs and wear-resistant tools, such as dies, measuring gages, chisels, punches, lathe centers, tool bits, files, and low-speed cutters. High carbon steel can be made very hard by heat treatment. When a

TYPES OF STEEL	SAE NUMBERS (General Series)	CHARACTERISTICS RESULTING FROM THE ALLOYING ELEMENT ADDED
Carbon Steels	1000	Surface Hardness and Strength
Nickel Steels	2000	Toughness
Chrome-Nickel Steels	3000	Toughness and Depth Hardness
Molybdenum Steels	4000	Eliminates Brittleness and Increases Depth Hardness
Chrome-Molybdenum Steels	4100	High Strength and Toughness
Chromium Steels	5000	Corrosion Resistance and Hardness
Chrome-Vanadium	6000	Depth Hardness and Toughness at Sub-Zero Temperatures
Tungsten Steels	7000	Hardness at High Temperatures
Chrome-Nickel-Molybdenum Steels	8000	Toughness and Strength - (General Purpose Steel)
Silicon-Manganese Steels	9000	Depth Hardness and Toughness Under Impact

53-1573

Figure 1-4. General characteristics of common alloys.

small amount of vanadium is added to high carbon steel, the product is called drill rod. Drill rod is superior to high carbon steel for cutting tool usage.

Nickel steels (SAE-2000 series) have better impact resistance at subzero temperatures than carbon steels and are harder and stronger. They are often used for aircraft structural bolts, clevises, pins, turnbuckles, washers, nuts, and similar hardware. They can be hardened by heat treatment.

Nickel-chromium steels (SAE-3000 series) are tough, strong, and hard and are used for aircraft engine parts, such as shafts, links, screws, bolts, nuts, washers, rivets, pins, pump parts, gears, and other aircraft parts that must be strong and tough. Their strength and impact resistance are not affected by subzero temperatures when they are properly heat treated. They can be hardened by heat treatment.

Molybdenum steels (SAE-4000 series) are all hardenable by heat treatment. Plain molybdenum steel is used for aircraft structural parts, such as pins, clevises, terminals, and bolts. Molybdenum steels are often alloyed with chromium or nickel, or both. These alloys are used for aircraft engine and structural parts, such as cams, gears, landing gear cylinders, bombracks, bolts, nuts, washers, hoisting eyes, piston pins, rocker arms, and similar parts.

Chromium steels (SAE-5000 series) are used for parts requiring high strength, depth hardness, and stainless properties. Engine piston pins and roller bearings are made of these steels.

Chromium-vanadium steels (SAE-6000 series) are used for high-strength engine parts, propeller blades, wrenches and similar tools, cylinder studs, and heavy-duty springs. They are not affected by subzero temperatures when they are properly heat treated.

Tungsten steels (SAE-7000 series) are used for high-speed cutting tools and dies and are very heat resistant.

Chromium-nickel-molybdenum steels (SAE-8000 series) are used for various aircraft structural parts. They are similar in application and properties to the molybdenum steels and originally were national emergency steels. When properly heat treated, these steels are not affected by subzero temperatures.

Silicon-manganese steels (SAE-9000 series) are very tough and shock resistant and are excellent chisel and punch steels. They are often used for coil and leaf springs but are brittle under impact at subzero temperatures.

Silicon-chromium steels (SAE-9000 series) are spring steels but are not recommended for subzero use.

Tool steels are steels suitable for the manufacture of cutting tools or other types of tools. High carbon steels, drill rod, tungsten steels, chromium-vanadium, and silicon-manganese steels all fall into this class.

Stainless steel is really a trade name but is commonly used in reference to any corrosion-resistant alloy. Corrosion-resistant steel can be a nickel-chromium steel (SAE-3000 series) or a chromium steel (SAE-5000 series). These steels are used where a high degree of corrosion and heat resistance is required. For example, these alloys are used extensively in the manufacture of jet engine parts and aircraft parts that are located around jet engines.

Exercises (204):

1. What two elements increase the machinability of a metal when added to it?
2. What element is alloyed with high carbon steel to produce drill rod?
3. List five uses of molybdenum steels when alloyed with chromium or nickel.
4. The SAE-8000 series steel are very similar to what other series of steels?
5. What types of steels can be classified as tool steels?
6. What are the two main alloys that can be used to produce corrosion-resistant (stainless) steels?
7. What characteristics do the SAE-3000 and SAE-5000 series steels have that make them useful in and around jet engines?

205. State the name, uses, and characteristics of various nonferrous metals.

Characteristics and Uses. The nonferrous metals group includes many metals that are used mainly for metal plating or as alloying elements—such as tin, zinc, silver, and gold. We are primarily concerned with the metals used for the manufacture of parts, such as aluminum, magnesium, titanium, nickel, copper, and their alloys.

Aluminum is a white lustrous metal, very light in weight, corrosion resistant, and an excellent conductor of both heat and electricity. Because of its light weight, it is one of the most important metals used by the aircraft industry. It is generally used in the form of an alloy, with copper, and manganese, silicon, magnesium, magnesium and silicon, or zinc as the main alloying materials. The term "aluminum" is used in reference to the various alloys as well as to commercially pure aluminum. Aluminum is used wherever weight reduction is a factor and extreme hardness and strength are not critical.

Aluminum in its commercially pure form (SAE-1000 series) is highly corrosion resistant. It cannot be hardened by heat treating, and it is used in applications that do not require much strength, such as brackets, tanks, electrical conduit, fluid lines, rivets, and welding rods.

Aluminum-copper alloys (AA-2000 series) are usually hardened by heat treating. These alloys are not as corrosion resistant as some of the other alloys and are often "clad." A clad alloy has a coating of a more corrosion-resistant metal, usually pure aluminum, but an aluminum-magnesium-silicon alloy is often used. Aluminum-copper alloys are among the strongest and most widely used alloys. They are used for aircraft parts, such as stringers, beams, spars, skin, ribs, bulkheads, fairing, tubing, and rivets.

Aluminum alloys whose main alloying element is manganese (AA-3000 series), silicon (AA-4000 series), or magnesium (AA-5000 series) are not usually hardenable by heat treatment. They are used for various aircraft parts such as propellers, fairings, fluid lines, etc; however, the 4000 series is primarily used as welding rod.

Aluminum-silicon-magnesium alloys (AA-6000 series) and *aluminum-zinc alloys* (AA-7000 series) are both hardenable by heat treating and are used for aircraft fittings, fairings, bulkheads, beams, ribs, skin, etc. The 6000 series alloys are of medium strength while the 7000 series alloys are the strongest group of aluminum alloys. AA-7075 is probably the best known alloy in this series and is widely used for various airframe structures and for highly stressed parts.

Magnesium is an extremely lightweight white metal. It weighs approximately two-thirds as much as aluminum. Because of its light weight, it is also an important aircraft material; however, it is subject to corrosion in a salt atmosphere.

NOTE: The machining of magnesium presents a fire hazard, because the fine chips produced by machining may ignite and burn intensely. Never use water or soluble oil (water and oil solution) as a coolant or as a cutting lubricant for magnesium. Water intensifies a magnesium fire.

Titanium is a lightweight metal that has a good weight-to-strength ratio. It is 44 percent lighter than stainless steel, yet it has about the same strength. It is also highly corrosion resistant. It is being used more and more by the aircraft industry. NOTE: Fine chips of titanium may also ignite; however, they do not ignite as easily as magnesium. Titanium alloys are used for aircraft frames, skins, and engine parts; for turbine engine parts, such as blades, discs, wheels, and spacer rings; for rocket motor parts; and for marine applications.

Monel is a nickel and copper alloy that comes in several variations. It is highly corrosion resistant, has high strength and toughness, and has temperature-resistant qualities. Monel alloys are not affected by subzero temperatures. These alloys have many uses on aircraft, such as hydraulic mechanisms, pitot tubes, oil cooler shells, rivets, air filters and fuel strainers. Some alloys containing aluminum or silicon can be hardened by heat treatment. These alloys are used for diaphrams, chains, gears, stop pins, bolts, surface controls, some structural parts, and springs operating at temperatures as high as 500° F.

Inconel is a nickel and chromium alloy suitable for high-temperature applications up to 2100° F. and is, therefore, used for various reciprocating, jet, and turbine engine parts. Springs operating at temperatures as high as 750° F. are made from this alloy. Subzero temperatures have no effect on inconel or inconel "X."

Inconel "X" is also a nickel and chromium alloy, suitable for high-temperature applications up to 1500° F; however, small amounts of aluminum, columbium, and titanium make it stronger and harder than inconel. It is used for manufacture of bolts and turbine rotors. Aviation brake drum springs and relief valve and turbine springs operating at temperatures up to 1000° F. are made from this alloy.

Copper is a reddish-brown colored metal that is an excellent conductor of both electricity and heat. The most common of the copper-base base alloys are brass and bronze. The chief alloying element in brass is zinc; in bronze, it is tin. Other copper-base alloys are beryllium-copper and copper-silicon. Nonsparking tools are made from a beryllium-copper alloy.

Brass is an alloy of copper and zinc. Pure copper is reddish brown and, as zinc is added, the color changes to yellow when the zinc content is approximately 30 percent. As the zinc content is further increased, the yellow color blends toward red. Brass is used for electrical fittings, radiator and cooler parts, turn-buckle barrels, rivets, hinge pins, lockrings, springs, tubing, bolts, nuts, and pump parts. Extremely cold temperatures do not reduce the strength of brass alloys. Naval brass is an alloy used where stronger, tougher, and more corrosion-resistant properties are required.

Bronze closely resembles brass in appearance. True bronze is a tin and copper alloy, but commercial bronzes also contain other elements. Bronze alloys are not affected by subzero temperatures. Plain bronze alloys are used for gears, bearings, bushings, valve guides, piston pins, thrust washers, and similar parts.

Aluminum bronze alloys have considerable strength, corrosion resistance, and hardness. When the alloy contains over 10 percent aluminum, it may be hardened by heat treatment. Aluminum bronze alloys are used for gears, guides, bushings, bearings, special bolts, valve parts, sleeves, screws, pins, and worm wheels.

Phospher bronze alloys are used for springs, fasteners, cotter pins, clutch discs, wrist pins, and parts needing antifriction properties, such as bushings and guides.

Silicon bronze alloys have high strength and corrosion resistance and are used for parts requiring these properties. Silicon bronze tubing is used for fuel, oil, air, and water lines.

Managanese bronze alloys have high strength, toughness, and corrosion resistance. They are used for such parts as gear-shifter forks, brackets, pumps, valve parts, marine parts exposed to sea water, parts for starting motors, and landing gear and tail-skid castings for aircraft.

Most of the nonferrous metals have good machinability qualities because they are usually softer than ferrous metals. Titanium and the nickel alloys (monel, inconel, etc.) are notable exceptions.

Exercises (205):

1. What aluminum alloys are widely used for aircraft parts, but because of their poor corrosion resistance must be "clad"?

2. What does the term "clad" refer to?

3. Some aluminum alloys are not usually hardenable by heat treating. What are the main alloying elements used in these alloys?

4. What is the machining characteristic that is common to both magnesium and titanium?

5. How is the composition of inconel "X" different from that of inconel and what are the resultant characteristics?

6. What is alloyed with copper to make brass? To make bronze?

7. What bronze alloy is used for making springs?

8. What are the general machinability characteristics of nonferrous metals? List the most notable exceptions.

1-3. Effects of Heat Treating

As a machinist you will probably not perform heat treating. You must, however, know the effects of heat treatment for metal parts. Most of the metals you work with in a machine shop are heat treated when you get them or will be heat treated after you have machined them. In this section we will discuss the steps in heat treating and the types of heat treating for ferrous and nonferrous metals.

206. Describe the basic steps involved in a heat treating operation, and explain their effects on the metal.

Heat Treating Steps. There are five basic heat treating processes; hardening, case hardening, annealing, normalizing, and tempering. Although each of these processes bring about different results in metal, all of them involve three basic steps; heating, soaking, and cooling.

Heating. Heating is the first step in a heat treating process. Many alloys undergo certain changes in structure when they are heated to specific temperatures. The structure of an alloy at room temperature can be either a mechanical mixture, a solid solution, or a combination solid solution and mechanical mixture. A mechanical mixture can be compared to concrete. Just as the sand and gravel are visible and held in place by the cement, the elements and compounds in a mechanical mixture are clearly visible and are held together by a matrix of base metal.

A solid solution is when two or more metals are absorbed, one into the other, and form a solution. You are probably most familiar with liquid solutions, but solutions may also be gaseous or solid. When an alloy is in the form of a solid solution, the elements and compounds forming the metal are absorbed into each other in much the same way that salt is dissolved in a glass of water. The separate elements forming the metal cannot be identified even under a microscope.

A metal in the form of a mechanical mixture at room temperature often goes into a solid solution or a partial solution when it is heated. Changing the chemical composition in this way brings about certain predictable changes in grain size and structure. This brings us to the second step in the heat treating process; soaking.

Soaking. Once a metal part has been heated to the temperature at which desired changes in its structure will take place, it must remain at that temperature until the entire part has been evenly heated throughout. This is known as soaking. The more mass the part has, the longer it must be soaked.

Cooling. After the part has been properly soaked, the third step is to cool it. Here again, the structure may change from one chemical composition to another; it may stay the same; or it may revert back to its original form. For example, a metal that is a solid solution after heating may stay the same during cooling, or change to a mechanical mixture, or to a combination of the two, depending on the type of metal and the rate of cooling. All of these changes are predictable and, for that reason, many metals can be made to conform to specific structures in order to increase or decrease its hardness, toughness, ductility, tensile strength, etc.

Exercises (206):

1. How many steps are involved in each of the five basic heat treating processes?

2. List the three steps in a heat treating process.

3. What are the different chemical compositions that various metals may attain or change to during the heating and cooling steps?

4. How can specific characteristics be obtained in a piece of heat treatable metal?

207. Name and explain the effects of the heat treating operations for ferrous metals, and state the heat treatment requirements for various metal parts.

Heat Treatment of Ferrous Metals. All heat treating operations involve, of course, the heating and cooling of metals. The common forms of heat treatment for ferrous metals are hardening, tempering, annealing, normalizing, and case hardening.

Hardening. A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. A few, however, can be hardened by cooling in air. Hardening increases the hardness and strength of the metal, but also increases the brittleness.

Tempering. Steel is usually harder than necessary and too brittle for practical use after being hardened, and severe internal stresses are set up during the rapid cooling of the metal. Steel is tempered after being hardened so as to relieve the internal stresses and to reduce the brittleness. Tempering consists of heating the metal to a specified temperature and then permitting the metal to cool. The rate of cooling usually has no effect on the metal structure during the tempering operation. Therefore the metal is usually permitted to cool in still air. The temperatures that are used for tempering are normally much lower than the hardening temperatures. The higher the tempering temperature used, the softer the metal becomes. High-speed steel is one of the few metals that becomes harder instead of softer after it is tempered.

Annealing. Metals are annealed to relieve internal stresses, to soften them, make them more ductile, and refine their grain structures. Metal is annealed by heating it to a prescribed temperature, holding the metal at that temperature for the required time, and then cooling it back to room temperature. The rate at which the metal is cooled from the annealing temperature varies greatly. Steel must be cooled very slowly if we are to produce maximum softness. This can be done by burying the hot part in sand, ashes, or some other substance that does not conduct heat readily (packing), or by shutting off the furnace and allowing the furnace and part to cool together (furnace cooling).

Normalizing. Ferrous metals are normalized to relieve the internal stresses produced by machining, forging, bending, or welding. Normalized steels are harder and stronger than annealed steels. Steel is much tougher in the normalized condition than in any other condition. Parts that will be subjected to impact and parts that require maximum toughness and resistance to external stresses are usually normalized. Normalizing prior to hardening is beneficial in obtaining the desired hardness, provided that the hardening operation is performed correctly. Low carbon steels do not usually require normalizing, but no harmful effects result if these steels are normalized. Normalizing is achieved by heating the metal to a specified temperature (which is higher than either the hardening or annealing temperatures), soaking the metal until it is uniformly heated, and cooling it in still air.

Case hardening. Case hardening is an ideal heat treatment for parts which require a wear-resistant surface and a tough cores–parts such as gears, cams, cylinder sleeves, etc. The most common case hardening processes are carburizing and nitriding. During the case hardening process, a low carbon steel (either straight carbon steel or low carbon alloy steel) is heated to a specific temperature in the presence a material (solid, liquid, or gaseous) which decomposes and deposits more carbon into the surface of the steel. Then when the part is cooled rapidly, the outer surface or case becomes hard, leaving the inside of the piece soft, but very tough.

Heat Treatment Requirements. The heat treatment of an aircraft part is usually specified by a technical order or on a drawing, blueprint, or microfilm. You will seldom, if ever, make the decision as to the heat treatment to give such items. At times, however, you will manufacture items that do not have the required heat treatment specified, such as locally designed tools and equipment. Then you must determine which of the mechanical properties (hardness, toughness, wear resistance, etc.) should be increased or decreased to provide the greatest efficiency. You will have to decide which of mechanical properties are the most important and which are least desirable. You do this by considering the job that the tool or part must do. For example, a cutting tool must be harder and have more wear resistance than the material it is to cut; but as hardness and wear resistance increase, brittleness increases and shock resistance decreases. A brittle tool with little or no shock resistance is of no value. In another example, brittleness is of great importance in a part that is designed to break under a given load or sudden jolt. Proper heat treatment of a tool or part controls the hardness which in turn increases or decreases the other mechanical properties.

When the heat treatment is not specified, you can usually find instructions for a suitable heat treatment of a particular metal in a reference publication such as *Machinery's Handbook* or in Technical Order 1-1A-9, *Aerospace Metals*. Figure 1-5 shows the recommended hardness for various tools and equipment. Also, the metals processing technician can be of great help to you in determining the heat treatment process since he or she will be performing the operation and is usually knowledgable in that area.

Exercises (207):

1. What are the five common heat treating processes for ferrous metals?

2. Generally, what happens to the hardness of a metal during tempering?

Kind of Tool	Hardness, Rockwell C
Arbor nuts, milling machine	46-52
Arbors, milling machine	46-52
Broaches	63-65
Centers, lathe	63-66
Chisels, cutting end	50-54
Clamps	46-52
Cutting tools	63-65
Drifts	45-48
Gears	30-35
Mandrels, lathes	63-66
Nuts, clamping	30-35
Punches, center	57-60
Screwdrivers	46-48
Taps	60-63
Woodworking tools	45-48
Wrenches, special	30-35

53-1572

Figure 1-5. Recommended tool hardness.

3. What is the difference between annealing and normalizing?

4. What are the two main characteristics of a case hardened part?

5. When you must determine the type of heat treatment that a steel part should receive, what should you consider?

6. What is the recommended hardness for a enter punch?

208. State the heat treating operations used on nonferrous metals, and explain their effects on the metals.

Heat Treatment of Nonferrous Metals. There are essentially two types of heat treating operations that can be performed on nonferrous metals: annealing and solution heat treating.

Annealing. Most nonferrous metals can be annealed. The annealing process consists of heating the metal to a specific temperature, soaking, and cooling to room temperature. The temperature and method of cooling depend on the type of metal. Annealing is often accomplished after various cold working operations because many nonferrous metals become hard and brittle after cold working. Also, annealing is used to remove the effects of solution heat treatment so that machining or working qualities can be improved.

Solution heat treatment. The tensile strength of many nonferrous alloys can be increased by causing the materials within the alloy to go into a solid solution and then controlling the rate and extent of return to an *altered* mechanical mixture. This operation is called solution heat treatment. After an alloy has been heated to a specified temperature, it is "quenched" or rapidly cooled which traps the materials in the solid solution attained during the heating process. From this point the process varies greatly depending on the metal. To be sure that the materials in the alloy don't revert back to their original configuration after a period of time, a process of *aging* or *precipitation hardening* must follow. In this process the materials in the alloy are allowed to change or to precipitate out of the solid solution under controlled conditions so that the resultant grain structure will produce a greater tensile strength in the metal than in its original condition. This precipitation process, depending on the alloy, can consist of simply aging the alloy at room temperature for a specified time before using it or aging it at an increased temperature for a specified time and then air cooling it, which is called artificial aging.

Aluminum alloys can be obtained in various conditions of heat treatment called temper designations. Figure 1-6 shows the various temper designations and the type of process to which they apply. The term "strain hardened" refers to aging or hardening that has been brough about by cold working the alloy. "Stabilizing" refers to a particular aging process that freezes or stops the internal changes that would normally take place in the alloy at room temperature.

Magnesium alloys can be subjected to all of the nonferrous heat treatments, but the different alloys within the series require different temperatures and times for the various processes. Copper alloys are generally hardened by working, but they can be annealed. The nickel alloys can also be annealed and certain types can be hardened by heat treatment. Likewise, titanium may be annealed (mostly to relieve machining or cold working stresses), but is not noticeably affected by heat treatment.

Now try a few more questions, and then we will discuss a few ways of checking the hardness of metals.

Exercises (208):

1. Why is annealing often accomplished after bending and forming operations on nonferrous metals?

Temper Designations

Symbol	Designation
—F	As fabricated.
—O	Annealed, recrystallized (wrought products only).
—H	Strain hardened.
—H1	Plus one or more digits. Strain hardened only.
—H2	Plus one or more digits. Strain hardened and then partially annealed.
—H3	Plus one or more digits. Strain hardened and stabilized.
—W	Solution heat treated—unstable temper. This designation is specified only when the period of natural aging is indicated.
—T	Treated to produce stable tempers other than —F, —O, or —H.
—T2	Annealed (cast products only).
—T3	Solution heat-treated and then cold-worked.
—T4	Solution heat-treated.
—T5	Artificially-aged only.
—T6	Solution heat-treated and then artificially-aged.
—T7	Solution heat-treated and then stabilized.
—T8	Solution heat-treated, cold worked and then artificially-aged.
—T9	Solution heat-treated, artificially aged and then cold-worked.
—T10	Artificially aged and then cold-worked.

53-1014

Figure 1-6. Temper designation of aluminum.

BEST COPY AVAILABLE

2. What does the term "solution heat treatment" mean?

3. Briefly explain "precipitation hardening."

4. What does "temper" mean in reference to aluminum?

5. An aging process for aluminum alloys that freezes the internal changes that would normally occur is known as _______ .

6. Various magnesium alloys may respond favorably to how many of the various nonferrous heat treatments?

7. How are copper alloys usually hardened?

8. What effect does heat treatment (other than annealing) have on titanium?

1-4. Testing for Hardness

When a machinist must modify metal parts or equipment, he must know the hardness of the metal if he is to determine the proper tools and the proper machining steps that will be involved. Determining the hardness of metal can involve the use of a simple handtool when great accuracy is not required or it can involve more complicated and more accurate equipment. The next objective will briefly cover the most common types of hardness testing.

209. Describe the common types of hardness testing, and explain the use of the Rockwell hardness tester.

File Test. One simple way to check for hardness in a piece of metal is to file a small portion of it. If it is soft enough to be machined with regular tooling, the file will cut it. If it is too hard to machine, the file will not cut it. You can use the file in the same way to determine the hardest of two pieces of metal; the file will cut the softest metal easier. When you use the file to check for hardness, be careful not to rub your fingers or hand on the file face or the work piece. The acid and oil from your hands can cause the file to slide over the work instead of cutting it. If that happens, it can easily be mistaken for a sign that the metal is too hard to cut with the file. At any rate, the file method should only be used in situations when the exact hardness is not required. Normally, when accuracy is required, you must take the part to the metals processing shop, where it can be checked with a Rockwell hardness tester.

Rockwell Hardness Tester. A machinist does not normally perform hardness testing with the Rockwell tester since it is a responsibility of the metals processing shop; however, you should have a basic understanding of how the Rockwell tester works. The principle of Rockwell hardness testing is based on the distance that a penetrator will penetrate a piece of metal.

There are other types of hardness testers available (Brinell, for instance), but the Rockwell tester is the most common type in the Air Force. It has been selected by the Air Force because it is simple to operate; it can test a great variety of metals of varying degrees of hardness; and it does not depend upon the judgment of the operator for accuracy. Figure 1-7 illustrates a Rockwell hardness tester, while figure 1-8 shows some of the attachments used with it. This tester uses the static principle and works on a leverage system. When the lever shown on the right side of the base in figure 1-7 is tripped, a predetermined load or weight forces a penetrator into the metal being tested. The hardness value, which depends upon the depth of penetration between the minor and major load, is indicated on the dial. The shallower the penetration, the higher the hardness number. The penetrator can be either a diamond or a hardened steel ball. The diamond (Brale) has a sphero-conical shape (a cone with a rounded point) and is precision cut and polished. The standard steel balls are either 1/16 inch or ⅛ inch in diameter, and ¼-inch or ½-inch balls are used for special tests.

Before the major load is applied, the test specimen must be securely locked in place to prevent slipping and to properly seat the anvil and penetrator. To do

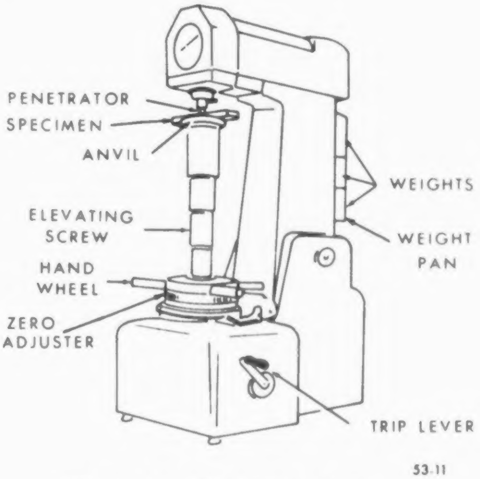


Figure 1-7. Rockwell hardness tester.

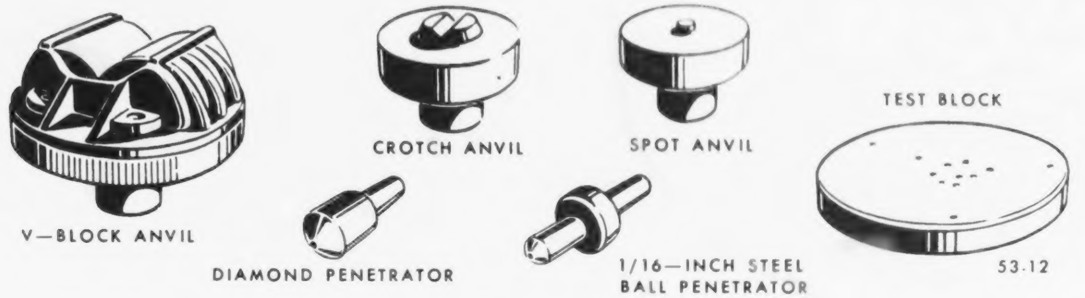


Figure 1-8. Rockwell hardness tester attachments.

this, a load of 10 kilograms (approximately 22 pounds) is applied before the lever is tripped to apply the major load. This preliminary load is called the minor load. The minor load is 10 kilograms, regardless of the major load or the penetrator used. When the tester is set properly, the machine automatically applies the 10 kilogram minor load.

The load that is applied to force the penetrator, shown in figure 1-7, into the metal is known as the major load and is measured in kilograms (1 kilogram is approximately 2.2 pounds). The major load can be 60 kilograms, 100 kilograms, or 150 kilograms, depending upon the material being tested. After the pointer has come to rest, the major load is removed. Then the hardness of the material can be read from the dial graduations.

The dial face of Rockwell tester (figure 1-9) contains several different scales. The "C" scale is used with the diamond penetrator for testing hardened steels. The "B" scale is used with the 1/16-inch steel ball penetrator for testing soft or annealed steel and some harder types of nonferrous metals. The "E" scale (not shown in figure 1-9) is used with the ⅛-inch steel ball for general nonferrous testing. In each case the major load is set at a certain weight for each particular scale to be used. These are the most commonly used scales; however, there are several others, depending on the major load and penetrator that is used. For this reason the scale designation should be given with Rockwell hardness members; for example, "Rockwell 50 C" shows that the "C" scale was used. Technical Order 1-1A-9, *Aerospace Metals*, gives detailed information on hardness testing of metals.

This concludes our chapter on metallurgy. In our next chapter we will discuss various lubricants and coolants and their applications in the Air Force machine shop.

Exercises (209):

1. How can you quickly determine the approximate hardness of a metal?

2. When testing for hardness with a file, why shouldn't you handle the file face with your bare hands?

3. Who will normally perform hardness testing on the Rockwell tester?

4. What is the name and shape of the diamond penetrator?

5. What is the purpose of the minor load?

6. Normally, what scale and penetrator should be used to check hardened steels with the Rockwell tester?

7. Which penetrator should be used for checking soft or annealed steel?

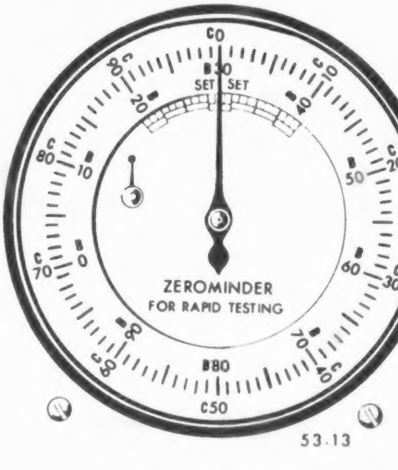


Figure 1-9. Dial face of a Rockwell hardness tester.

Lubricants and Coolants

"WHEELS MAKE THE world go round." Although this is not true in the literal sense of the word, wheels do play an important role. In order for a wheel or any other object such as a gear, cog, shaft, or pulley to turn properly, it must have some form of lubrication.

Lubrication may be in the form of grease or oil for moving machine parts, hydraulic fluid for control surfaces of high performance aircraft, or a cutting and cooling oil for use in machining other metal parts. In this chapter we discuss each of these lubricants and their uses in an Air Force machine shop.

2-1. Machine Lubrication

In every machine shop, bearings of one kind or another are without number. There are bearings which revolve high speed spindles and slow turning trunnions, and bearings which guide delicate mechanisms or support heavy masses, and they all have to be lubricated. In the machine shop the machinist is concerned with the lubrication of the equipment or of some mechanism he may be building. Therefore the failure to properly lubricate the equipment may cause machine failures which, in turn, will hold up production and maintenance work. You can readily see that lubrication is highly important in the machine shop.

210. State the purpose and action of lubrication on shop machinery.

Purpose of Lubrication. All shop machinery involves the use of moving parts. When one part must move on another part, some type of bearing is normally used between them to prevent wear on the machine parts.

Bearings, generally speaking, are supports or guides for the moving part of machines, engines, and shaftings. Some types are *plain* bearings of the radial, thrust, or slipper types; and some are *antifriction* bearings, both ball or roller bearings, each of which may be of the radial or thrust bearing type. The efficiency of all machine tools depends in a large measure upon the ability of these parts to operate without loss of power, excessive wear, or high maintenance cost. The most important cause of inefficiency is friction. Friction is defined simply as resistance to motion. Suppose for example, that two flat metallic surfaces rest one on the other, as shown in figure 2-1. It would appear that smoothly ground surfaces, such as these, would offer little or no resistance to the movement of one over the other. When these surfaces are greatly magnified, however, they are found to be made up of many microscopic irregularities, such as the hills and valleys shown on the flat plates in figure 2-2,A. The interlocking of the irregularities produces a definite resistance to the motion of one surface over the other. The force necessary to start movement is great. After the movement is underway, the force required for continued motion is less because inertia prevents the moving surface from dropping into another interlocking position. This condition would be especially prevalent in a slipper bearing operated without lubricant. The result would be the destruction of the rubbing surfaces. By placing a film of oil between the bearings, as shown in figure 2-2,B, you can see that the two surfaces are separated from each other, thus preventing the surface irregularities from interlocking and allowing one piece to slide over the other more easily.

In some instances lubrication has another purpose as well as the reduction of friction. It is used in many gearboxes to carry away heat buildup from the operating gears. This is accomplished by allowing the lubricant to flow or splash over the gears. Of course, it is still helping to overcome friction between the gears at the same time.

Exercises (210):

1. What is the main purpose of lubrication on shop machinery?

2. How does lubrication prevent or decrease friction between moving parts?

3. What other purpose can a lubricant serve as well as overcoming friction?

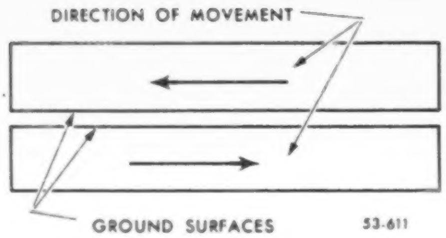


Figure 2-1. Ground metallic surfaces.

211. Describe plain bearings and explain the action of lubricants on them.

Plain Bearings. Plain bearings are generally made from material such as bronze, which is hard enough to wear well, but softer than the material that it contacts. When a plain bearing is pressed into a hole, it is known as a bushing. Bushings can be plain or flanged, as shown in figure 2-3, and are replaced when they become worn. Another type of plain bearing is the thrust bearing, also shown is figure 2-3, which is designed to resist movement of a shaft toward either end. Still another type of bearing is the slipper type (not pictured). Slipper bearings guide moving parts in a straight line, such as the ones between a lathe saddle and the ways. Plain bearings depend upon lubricants to reduce friction and wear. The lubricants do this by introducing a fluid or plastic medium between moving metallic surfaces. This fluid is in the form of a lubricating film which separates the surface enough to prevent metallic contact.

There are special materials in use today that do not require constant relubrication when fabricated into plain bearings because they have lubricating qualities in the material itself. For example, certain types of bronze has oil impregnated into the pores of the metal. It is known as "oilite" and is very useful for bearings that cannot be lubricated regularly.

Plain bearings are widely used in aircraft and associated equipment. They are used in such places as airframes, engines, trunnions, connecting rods, and control rods. You should always consult the applicable technical order before you attempt to remove, manufacture, or replace plain bearings because each one is designed specifically for a particular spot and cannot normally be interchanged with any type.

Exercises (211):

1. Describe the thrust type of plain bearings.

2. What does lubrication do when used with a slipper bearing?

3. Explain how some plain bearings can be operated efficiently without the addition of lubricants.

212. Describe the various antifriction bearings, and state the lubrication methods and problems regarding them.

Antifriction Bearings. The use of antifriction bearings is steadily increasing on all types of machinery. Antifriction bearings offer less resistance to starting motion. Their motion, instead of a sliding motion, is theoretically a rolling motion. A ball bearing consists of an outer race and an inner race separated by freely moving balls, as shown in figure 2-4. The outer race may be fixed to the bearing housing, in which case the inner race is mounted to the rotating shaft. Another type of antifriction bearing, which uses balls to roll on is a ball bearing thrust bearing, as shown in figure 2-5. The substitution of rolling motion for the sliding motion of plain bearings lessens the friction or resistance resulting from the contacting surfaces. In roller bearings, cylindrical or tapered rollers are employed instead of balls, as shown in figure 2-6. Antifriction bearings have a longer life than do plain bearings. The problem in the lubrication of antifriction bearings is not the actual lubrication as much as it is the prevention of abrasion, corrosion, and the accumulation of harmful deposits. Abrasion is prevented by a grease that forms a seal between the shaft and the bearing housing which excludes dust and grit. Antifriction bearings may be lubricated either by oil or grease. Bearings that are lubricated by oil are open so that the oil can get to the balls or rollers and races. Usually the type that is lubricated with grease is the sealed type in which the sides of the bearing have sealing rings that hold the grease in and around the balls and races.

Exercises (212):

1. How do antifriction bearings differ from plain bearings?

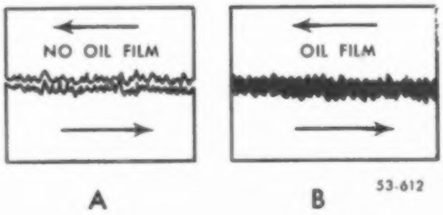


Figure 2-2. Magnified ground surfaces.

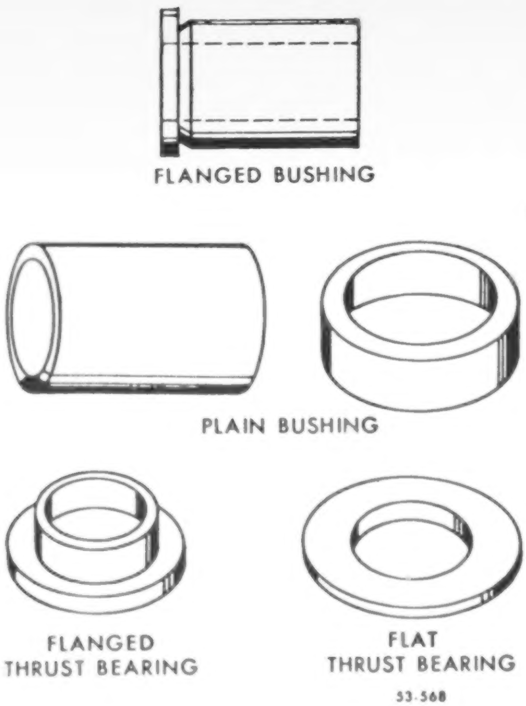


Figure 2-3. Bearings and bushings.

2. Briefly describe how roller bearings differ from other types of antifriction bearings.

3. You must design a lubrication system for an antifriction bearing. What will be your biggest problem in assuring long bearing life?

4. An antifriction bearing with sealing rings on the sides is lubricated with what kind of lubricant?

213. Describe the types and uses of various oiling systems and the operation of various oiling devices.

Oiling Systems. There are four basic types of oiling systems which we discuss: circulation, splash, bath, and ring and chain.

Circulation. This system is employed on practically all types of automotive and aircraft engines, as well as on a variety of machine tools. This type of oiling is used when lubrication is critical and when a large volume of oil is required for cooling, as well as for lubrication. The oil is pumped to the parts of the machinery by an oil pump, which is usually built into the machine.

Splash. This system is found on many types of machinery. The oil is contained in a gear housing on most machine tools and the gear teeth dip into the oil and splash it over the parts needing the lubrication. It then drains back to the sump or bottom of the housing where it is reused.

Bath. Frequently this system is employed for the lubrication of thrust bearings or vertical step bearings. In this method the bearings are always submerged in oil, which provides cooling as well as lubrication.

Ring and chain. In this system the oil is carried from a reservoir in the bearing housing to the top of the bearing by means of rotating rings or chains which revolve loosely on the revolving journal. The ring and chain oiling system is often found on low-speed machinery.

Oiling Devices. A number of different methods of getting the lubricant to the moving parts of the machinery may be used. We briefly discuss some of these methods.

Drop-feed cups. Drop-feed cups supply a regulated gravity feed of lubricant to parts of many machines.

Wick-feed cups. Wick-feed oilers use the principle of capillary action from a reservoir through the wick to the bearing surface.

Bottle feed cups. Bottle oilers differ from the ordinary drop-feed and wick-feed oilers in that they supply a more continuous, though extremely small, amount of oil to the bearing during the intervals when they are feeding.

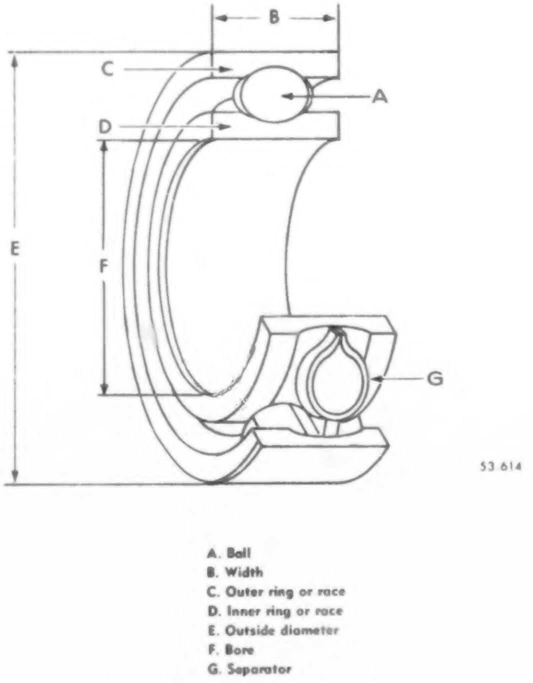
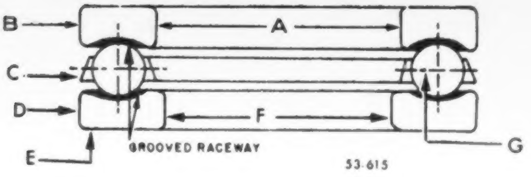


Figure 2-4. Antifriction ball bearings.



A. Large bore
B. Large bore washer
C. Separator
D. Small bore washer
E. Face
F. Small bore
G. Ball

Figure 2-5. Ball thrust bearing.

Exercises (213):

1. How does the splash oiling system differ from the circulation system?

2. Describe the ring and chain oiling system.

3. Bottle oilers depend on gravity to move the oil to the bearing. List two other oiling devices and state the principle that causes the oil to dispense from each.

214. State the characteristics and uses of various types of lubricants, and specify how to determine exact lubrication requirements for shop machinery.

Oil Lubricants. The following are some of the characteristics that go to make up good lubricating oils.

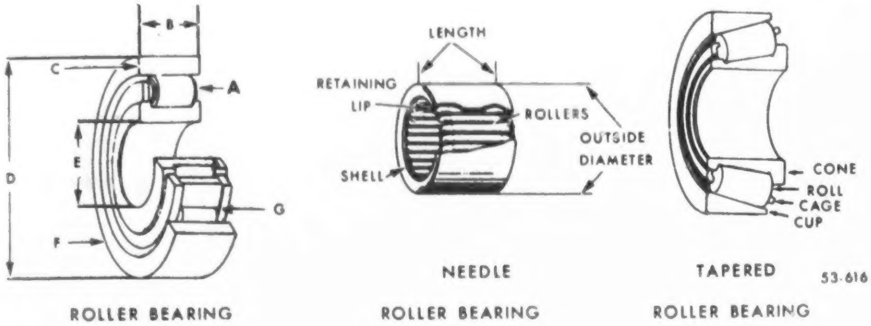
- High chemical stability.
- Rapid separation from water.
- Maximum resistance to detrimental influence of impurities.
- Maximum film strength and lubrication.
- Minimum variation in viscosity with temperature changes.

Viscosity refers, in part, to a fluid's ability to resist flow and to maintain a film between the surface; in other words, the thicker the oil, the higher the viscosity. The highest viscosity oil is not always the best one to use. Higher viscosity oils have a disadvantage in that they cause a waste of power needed to overcome the friction of the oil itself. The best oil to use is normally the lowest viscosity that will maintain a film between the surfaces throughout the operating temperature range.

Grease Lubricants. Under certain conditions the plastic nature of a soap-thickened oil is preferable to just oil itself. Such a mixture of oil and soap makes up greases. The resulting lubricant is capable of forming a plastic lubricating film, thus minimizing friction, wear, loss of power, and leakage. Grease is used on various friction and antifriction bearings. Note some of the types of greases in the following paragraphs.

Lime-soap greases. These greases are commonly known as cup greases and they are recognized by their smooth texture. Every lime-soap grease is essentially an emulsion of oil and lime-soap. These greases are excellent under conditions where the operating temperature is not high, where there is frequent application, and where there is no excessive churning action.

Soda-soap greases. These greases are noted for their fibrous texture. They can withstand higher



ROLLER BEARING

NEEDLE ROLLER BEARING

TAPERED ROLLER BEARING

A. Roller
B. Width
C. Outer ring
D. Outside diameter
E. Bore
F. Face
G. Separator

Figure 2-6. Roller bearings.

temperatures and are less likely to separate from agitation or churning. They have good resistance to oxidation and deterioration. Soda-soap greases emulsify with water and their use is impractical in or around water.

Metallic-soap greases. These greases are specialty products of a very adhesive nature. Because they form an exceptionally sticky lubricant, they are suitable for service where only small quantities of lubricant may be used to prevent throwing or dripping.

Solid Lubricants. Such solids as graphite, molybdenum disulfide, lead, babbit, silver, or metallic oxides are often used as lubricants. Though most of them are used in conjunction with fluid or grease, they can be and often are the only means of lubrication. They have certain inherent limitations that must be considered. First, is their inability to carry away heat. Second, they cannot be reused or replaced as are oils and greases. Third, they cannot be applied as oil and grease are. They must be bonded to the bearing surfaces by plating, fusing, or by chemical or thermal deposition.

Lubrication Requirements. All machine tools have definite lubrication requirements for such things as spindle bearings, work heads, ways, lead screws, gearing, and various bearings in general. All these require lubricants with the proper chemical stability, proper viscosity of oil or consistency of grease, and high film strength. Because there are so many oil companies refining lubricating oils and greases under so many different trade names, it is difficult to make any recommendations on the kind of oil or grease to use on the operating parts of machine tools. For this reason it is always best to consult the operator's manual on the lubrication needs of the machine. Usually the lubricant recommendations are very general in the operator's manual, while each oil company recommends a specific brand of lubricant. It is up to the machinist to convert the general lubricant specification from the operator's manual to a corresponding specification as listed by the manufacturer. Oils and greases are also made by oil companies to meet certain specifications as set down by the Government.

Exercises (214):

1. List at least four of the five characteristics of a good lube oil.

2. When you must select a lube oil for a piece of shop machinery, what viscosity should you normally choose?

3. You must select a type of grease to use in a high temperature mechanism that will be subjected to water moisture and will not be easily relubricated. What type of grease should you choose?

4. State the two undersirable characteristics of solid lubricants.

5. How can you determine which lubricant is exactly right for a particular machine?

2-2. Hydraulic Fluids

More and more machine tool manufacturers are using hydraulic power to operate practically every type of machine. Because of this, many of the machines you will use in the Air Force do have or soon will have hydraulically operated parts or systems on them. Therefore you should have at least a basic understanding of hydraulic fluids. In this section we will discuss the use of hydraulic fluid and some of the various types of fluids in use.

215. Identify the advantages and uses of various types of hydraulic fluids, and explain how they should be stored.

Hydraulic Fluids. The fact that industry relies heavily on hydraulic power for machine tools is due largely to the flexibility, smoothness, and simplicity with which hydraulic power may be applied. Many complex controls on various machine tools may be greatly improved and simplified by the use of hydraulic actuation. For example, some of these controls are found in hydroshift lathes, in which the speed may be changed while the machine is still running. Other advantages of hydraulic controls in machines are rapid tool approach, rapid tool return, and smooth vibrationless action, which is not affected by changes in loads. Cushioning effect, which often tends to improve surface finish, is still another advantage of hydraulically controlled machines. These are just a few of the many advantages of hydraulic power. These various machines employing hydraulic power need to be serviced. Extreme care should be used in changing or adding to the hydraulic fluids of these machines. Be sure to always check the operator's manuals for the proper type of hydraulic fluid. The use of improper fluids can cause severe damage to the seals in the machine and render the machine useless until repairs can be made.

Types of Hydraulic Fluids. There are several types of fluids which are used in hydraulic equipment. They are referred to as "hydraulic fluids" and "cleaning agents."

Petroleum-base fluid. One petroleum-base fluid is specified by MIL-H-5606. Petroleum-base fluid (5606) is dyed red for easy identification. It is generally supplied in 1-quart and 1-gallon containers and is available in one grade only. This one grade has an operating range of -65° F. (-53.9° C.) to +275° F. (135° C.). The advantage of this wide operating range is the ability of the fluid to perform adequately in summer and winter temperatures. The seals required with the petroleum-base fluid may be synthetic rubber, leather, or metal composition.

Vegetable-base fluid. Vegetable-base fluid, Specification MIL-H-7644, as it is presently known, was widely used in hydraulic systems using natural rubber seals. It has a bluish color, readily distinguishable from the petroleum-base type. However, this vegetable-base fluid is becoming obsolete.

Synthetic-base fluid. Some of the hydraulic systems used in high-speed supersonic aircraft require specially developed hydraulic fluids that have an operating range of abnormally high temperature. The main reasons for using this type of fluid are the close tolerances of the variable actuating units, the specially designed metering valves, and the overall heat generated by the supersonic speed of the aircraft.

Storage of Hydraulic Fluids. Hydraulic fluids should be stored in the same way as all flammable liquids. Care should be taken to prevent contamination. Cans that have been opened should be properly sealed to insure that the fluid will not be contaminated. Water, metal chips, dust, and other solids, if induced into the hydraulic system, could cause damage. Fluids should also be stored in properly marked containers.

Exercises (215):

1. What advantage of hydraulically operated machines often improves the surface finish?

2. Which type of hydraulic fluid will you most likely use in a surface grinder for operating the reciprocating table?

3. When storing hydraulic fluids, you must consider the location and the type of container. Why?

2-3. Cutting Lubricants and Coolants

With today's high-speed machinery and sophisticated metals, much heat is generated during many machining operations. This is damaging to the work and can quickly ruin a cutting tool. One way to combat this heat buildup is to use a cutting oil or coolant, which we will discuss in this section.

216. Specify the purpose, use, and application methods of cutting lubricants and coolants, and select the best one for use on particular metals.

Cutting Lubricants and Coolants. The primary purpose of a coolant is to carry away cutting tool heat. The various chemically active cutting fluids also reduce the cutting forces and thus ease the machining of metals. Operations that are performed at high speeds can benefit from a cutting fluid. High cutting speeds generate high temperatures at the tool point which causes the tool to lose its hardness. The use of coolants permits higher cutting speeds without increased tool temperature. In machining operations there are two methods of introducing cutting lubricants or coolants to the work. The most common method is the "conventional method" in which an abundance of coolant is flooded over the entire work and tool surfaces, as shown in figure 2-7. A disadvantage of this method in some cases is that the fluid cannot be applied close enough to the chip interface to perform its cooling function. Another method is the "jet cooling" application of cutting fluid to the work and tool, as shown in figure 2-8. The theory behind this method is that the coolant is forced to the cutting edge of the tool and interface of the chip to reduce tool tip temperature.

Types of Cutting Lubricants and Coolants. There are no hard and fast rules for the type of cutting fluid to use; an actual test with the tool or operation and material is by far the best test. The following general types of cutting oil and emulsions are used in most machine tool operations.

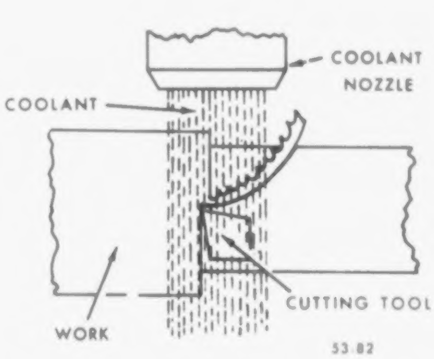


Figure 2-7. Conventional method of cooling a cutting tool.

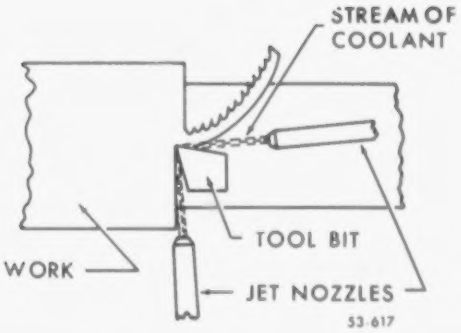


Figure 2-8. Jet method of cooling a cutting tool.

Sulfurized oils. The development of sulfurized oils was a great step forward in the development of cutting oils. One point about sulfurized oil that makes it useful as a cutting oil is that it helps to prevent the tendency toward welding of the chip to the tool tip and the consequent scuffing of the work and the tool deterioration.

Chlorinated oils. Chlorinated oils, like sulfurized oils, have a wide range of uses. Since they have low viscosity, many machinists feel that these light bodied oils are better coolants and penetrants. These oils are not as well established as are the sulfurized oils.

Soluble oils. Soluble oil products, when mixed with water to form emulsions, have been widely used, mainly as coolants, in machining operations. This type of coolant has proved very satisfactory for lathe and milling machine work where cooling is an important factor. Some machining operations benefit by a combination cutting oil and coolant where the reduction of tool wear and a cooling action are necessary. Most manufacturers of water-oil emulsion coolants add a rust inhibitor to the solution to prevent rusting of machine part caused by the water in the coolant.

Lard oils. Lard oil was widely used in the past, but with the development of sulfurized and other treated oils, it has gradually lost out in popularity. It may still be preferable for some turning operations, such as threading, but any fluid fatty oil, such as peanut oil or olive oil, will do just as well. Also, it may be used as a coolant with water by adding sal soda to emulsify the solution, but then it has a disadvantage in that the coolant becomes rancid with age.

Mineral oils. All cutting fluids that are extracted from petroleum are classified as mineral oils. Mineral seal oil and kerosene are examples of mineral oils. They are best suited for light machining operations such as on free-machining steels and nonferrous metals; however, they can be mixed with sulfurized or chlorinated oils for certain heavier machining operations.

Selection of Cutting Lubricants. As was stated earlier, no hard and fast rules can be applied to the selection of cutting fluids. The selection of the type of fluid depends upon the machinability of the metal and various other factors. The following recommendations (and those made in figure 2-9) are made as a general guide in the selection of cutting fluids for use on various metals:

Steel: If soluble oil is suitable, use a mixture of 1 part of oil and 10 to 20 parts of water. If the soluble oil tends to corrode the work, mineral oil may be preferable. For steels that take a great deal of tool pressure to cut, a sulfurized oil may be used. In cutting hard steel a chlorinated oil may be preferable.

Brass: Soluble oil or a mineral-lard oil are used for brass. In some cases a cutting oil would be preferable because of its lubrication. Brass castings are usually machined dry.

Monel Metal: Emulsions usually give a much longer tool life. Sulfurized oils tend to aid in breaking of the chip, and this may be preferable in some cases.

Aluminum Alloys: For many machining operations soluble oil is good. There are many recommendations for cutting fluids to be used on aluminum. Here are three recommendations: (1) From 90 percent kerosene and 10 percent lard oil to 50 percent kerosene and 50 percent lard oil, (2) 85 percent soluble oil and 15 percent kerosene, and (3) 50 percent kerosene, 40 percent lard-oil and 10 percent chlorinated solvent.

Cast Iron: Cast is usually machined dry. However, soluble oil emulsions may be used to hold down the amount of dust around the machine.

Exercises (216):

1. State the main purpose of a coolant; of a cutting lubricant.

2. Explain why the jet cooling method is usually better than the conventional method for high-speed cutting operations.

3. You must turn a piece of tough alloy steel at a high cutting speed. What type of coolant should you use to obtain the best cutting action as well as cooling qualities?

4. Lard oils are not considered to be soluble oils; however, they can be mixed with water to increase their cooling ability under certain conditions. Explain.

Metal	Turning	Milling	Drilling	Tapping
Aluminum	Mineral Oil with 10% Fatty Oil	Soluble Oil	Soluble Oil	Lard Oil
Alloy Steel	Sulphurized Mineral Oil	10% Lard Oil with 90% Mineral Oil	"	30% Lard Oil 70% Min. Oil
Brass	Mineral Oil with 10% Fat-	Soluble Oil	"	10% to 20% Lard Oil with Mineral Oil
Tool Steels	25% Lard Oil with 75% Mineral	Soluble Oil	"	25% to 40% Lard Oil with Mineral Oil
Low Carbon	"	Soluble Oil	"	"
Copper	Soluble Oil	"	"	Soluble Oil
Monel	"	"	"	25% to 40% Lard Oil with Mineral Oil
Malleable Iron	"	"	"	Soluble Oil
Bronze	"	"	"	20% Lard Oil with 80% Mineral Oil
Cast Iron	Dry	Dry	Dry	Dry
Magnesium	10% Lard Oil with 90% Mineral Oil	Mineral Seal Oil	Light Mineral Oil	20% Lard Oil with 80% Mineral Oil

NOTE: Never use soluble oil when machining magnesium. Water causes magnesium to burn more intensely.

53—131

Figure 2-9. Cutting lubricants.

5. Of the three given types of cutting fluids, select the best one to use when machining each of the following metals:

Given: Mineral oils, lard oils, soluble oils.

a. Aluminum ____________
b. Monel ____________
c. Magnesium ____________
d. Copper ____________

Power Cutoff and Contour Machines

THIS CHAPTER COVERS the various types of cutoff machines and the contour machine. Most of the machining jobs that you do will start with one of these machines, and in the case of the contour machine, many of your jobs can be done entirely on it. Although these machines are fairly simple compared to some of the other shop machinery, they are, nevertheless, dangerous if not used properly. Pay close attention to the safety practices and hints as you study this chapter.

3-1. Power Cutoff Machine Work.

In this section we will take a brief look at the power hacksaw. We will discuss the various parts of the machine, the operating procedures, and the blade selection requirement.

217. State the main parts of the power hacksaw, and specify the purpose and use of each.

Power Hacksaw. Many Air Force machine shops no longer have a power hacksaw. Instead they have a band cutoff saw which we will discuss later in this chapter. At the present time, though, there are still enough power hacksaws around to warrant our brief review of them. Figure 3-1 shows a typical power hacksaw and identifies its main parts, some of which we will now discuss.

Base. The base of the saw usually contains a coolant reservoir and a pump for conveying the coolant to the work. The reservoir contains a series of baffles which cause the chips to settle to the bottom of the tank. A table which supports the vise and the metal being sawed is located on top of the base and is usually referred to as part of the base.

Vise. The vise is adjustable so that various sizes and shapes of the metal may be held. On some machines the vise may be swiveled so that stock may be sawed off at an angle. The size of a power hacksaw is determined by the largest piece of metal that can be held in the vise and sawed.

Frame. The frame of the saw supports and carries the hacksaw blade. The machine is designed so that the saw blade contacts the work only on the cutting stroke. This action prevents unnecessary wear on the saw blade. The cutting stroke is usually the draw or back stroke. Many machines have a device that automatically turns off the feed and returns the frame to the up position when the work is sawed through.

Speed change mechanism. The shift lever allows the number of strokes per minute to be changed so that a variety of metals may be sawed at the most effective speeds. Some saws have a diagram on them showing the number of strokes per minute when the shift lever is in different positions; others are merely marked "F," "M," and "S" (Fast, Medium, and Slow). CAUTION: On most saws the motor must be turned off before the shift lever is moved. The saw may be damaged if this is not done because the transmission is not synchromesh.

Adjustable feed clutch. The adjustable feed clutch is a ratchet and pawl-type mechanism that is coupled to the feed screw. The feed clutch may be set to a desired amount of feed in thousandths of an inch. Because of the ratchet and pawl action, the feed takes place at the beginning of the cutting stroke. The clutch acts as a safety device and permits slippage if too much feed pressure is put on the saw blade. It may also slip because of a dull blade or if too large a cut is attempted. This slippage helps prevent excessive blade breakage.

Exercises (217):

1. State the name of the two parts of the power hacksaw that support and grip the work.
2. What is the part of the power hacksaw that determines its size designation? Explain.
3. What should always be done prior to operating the speed change mechanism?
4. State the two parts of the adjustable feed clutch that permit the blade to be fed into the work at the beginning of each stroke.

218. Describe operating procedures and the blade selection process for the power hacksaw.

279

Power Hacksaw Operation. To saw with maximum efficiency and to reduce blade breakage and wear, (1) the sawing speed must be correct, (2) the work must be properly positioned and secured, and (3) the correct saw blade must be used. Since you will use the power hacksaw along with nearly every job you do in the shop, you should thoroughly understand its operation.

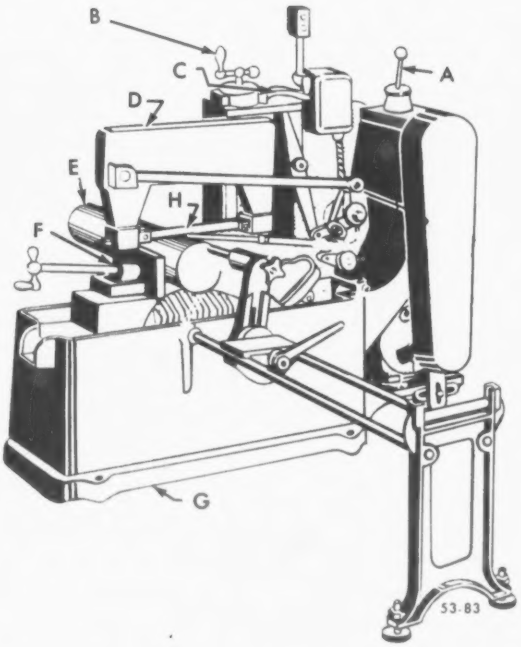
Speed and feed. Selecting the proper speed and feed for sawing is important. If the saw is operated too slowly, time is wasted; if too rapidly the saw blade wears excessively or it may break. Remember, however, that the condition of the hacksaw may require operating it at lower speeds and feeds than those recommended.

The *speed* (number of strokes per minute) of the hacksaw is determined by the type of metal being machined. A rule of thumb is: the harder the material, the slower the speed. CAUTION: Never attempt to saw hardened steel. The blade may snap, causing possible injury.

Feed is the distance the teeth penetrate the metal per stroke. It is usually stated in thousandths of an inch. For example, if the feed is set at 0.010, the depth of the saw cut is increased 0.010 inch on each stroke. Improper feed is one of the most frequent causes of hacksaw blade failure. If the feed is too light, it can cause rapid dulling of the blade teeth. The use of too heavy feeds cause blade breakage, chipped out teeth, or crooked cuts. For a 2-4 inch diameter piece of mild steel, a feed of 0.009 inch and a speed of 125-145 strokes per minute is recommended. The same size piece of stainless steel would require a feed 0.006 inch and a feed of 60-75 strokes per minute.

Holding work. Work to be sawed should be held by the vise. Before the vise is tightened, determine the location of the cut by measuring from the teeth of the blade to the end of the material or by aligning a layout line with the edge of the sawteeth. Be sure that the cut is not made on the wrong side of the line. Because of "runout" (the blade not sawing straight down), 1/16 inch extra length should be left on the work piece to enable the ends to be machined square. Long or heavy pieces of stock must be supported near the ends by workstands so that the cut is made perpendicular to the work axis. If the stock does not extend the full length of the vise jaws, a piece of scrap of the same size is placed at the opposite end of the vise. This prevents the vise jaw from tightening unevenly and possibly working loose.

Blade selection. Power hacksaw blades come in a variety of pitches (number of teeth per inch) and thicknesses. The thickness of blades varies from 0.030 inch to 0.100 inch. The thicker blades are intended for heavy-duty applications involving heavy feeds. Hacksaw blades vary in pitch from 2 ½ teeth to 18 teeth per inch. A blade having 14 teeth per inch is a good choice for general work. An 18-pitch blade is preferred for sawing tubing and pipe. Blades with a pitch of 6 to 10 teeth can be used effectively with aluminum and brass. Coarse-pitched blades are used on softer materials and fine-pitches blades on harder ones, but never less than 3 teeth should be in contact. If the pitch is too coarse, the teeth may straddle the metal and be ripped off. When a hacksaw blade is replaced, the new blade must be placed under tension by tightening the blade tightening nut. If insufficient tension is applied, the blade will not saw straight, or it may break. The teeth must face in the direction of the cutting stroke. NOTE: After you replace a worn or broken blade on a partially sawed job, do not attempt to saw with a new blade in the original cut. The new blade will usually stick and be damaged or broken. The work should be turned over and a new cut should be started from the opposite side.



A. Shift lever
B. Saw frame raising lever
C. Feed lever
D. Blade frame
E. Work
F. Adjustable vise jaw
G. Base
H. Saw blade

Figure 3-1. Power hacksaw.

Exercises (218):

1. What three conditions must be satisfied before the power hacksaw can be efficiently operated?

2. Normally, how is the speed affected as the material to be cut gets harder?

3. You must saw 1 inch off the end of a 2-inch diameter rod that is only 3 ½ inches long. How should you secure it in the vise to prevent it from working loose?

4. Several pieces of alloy steel have just been sawed on the power hacksaw, but now you must cut several pieces of 4-inch diameter aluminum. What changes should you make in the setup of the machine?

219. Specify purpose and use of the various parts of the band cutoff saw and state the maintenance requirements for it.

Band Cutoff Saw. As we stated before, the band cutoff saw is taking the place of the power hacksaw in Air Force shops. Figure 3-2 shows a typical band cutoff saw. It does the same job as the power hacksaw, but more efficiently. The blade of the band cutoff saw is actually a continuous band (figure 3-2,J) which revolves around a drive wheel and idler wheel in the band support frame (figure 3-2,I). Two band guides (figure 3-2,K) use rollers to twist the band so that the teeth are in the proper cutting position between them. The guides are adjustable and should be adjusted so that they are just slightly farther apart than the width of the material to be cut. This will give maximum support to the saw band and help to assure a straight cut.

The *vise* on the band cutoff saw is much like the one on the power hacksaw. However, the band cutoff saw has a much greater capacity for large size stock than does the power hacksaw. the stationary jaw (figure 3-2,B) can be set at several angles. The movable jaw automatically adjusts to whatever position the stationary jaw is in when the vise handwheel (figure 3-2,A) is tightened.

The band cutoff saw is hydraulically operated by controls on a control box (figure 3-2,H) which is located on the front side of the machine (figure 3-2 is a rear view). A motor and pump assembly (figure 3-2,D) supplies hydraulic fluid from a reservoir in the base to a cylinder which raises and lowers the support arm and also controls the feed pressure and blade tension. A speed and feed chart is sometimes provided on the machine, but when it is not, consult the operator's manual for the proper settings for various cutting operations.

A coolant pump (figure 3-2,G) is located in the other leg of the base which serves a coolant reservoir. The coolant cools the saw band and also washes away the chips from the cut before they can clog the band. Therefore you should be careful to keep the coolant tank properly filled, and be sure that it is used.

Perhaps the most abused maintenance requirement on the cutoff saw is cleanliness. Unfortunately it is not uncommon for a person to use the saw and then walk off without cleaning it. The cutoff should be cleaned *every* time you use it; the same as you would clean a lathe or a milling machine. It helps assure the continued efficient operation of the saw and also makes it a lot easier for the next person to use the machine. Along with keeping the machine clean, it should also be lubricated on a regular basis. Consult the operator's manual for the lubrication points and type of lubricant to use. Before you start the machine, you should always check the condition of the saw band. If it is dulled or if it has teeth broken out, it should be replaced. The pitch of the band teeth should be selected based on the type of material to be cut. the harder materials and thin walled tubing requires a higher pitched band while softer materials usually cut better with coarse pitched bands. Another item to check prior to starting the machine is hydraulic fluid level in the hydraulic reservoir. If the level is allowed to get too low, the machine will not function properly, if at all! Be sure to use the proper type of fluid as specified in the operator's manual.

Exercises (219):

1. What is the purpose of the saw band guides other than to support the saw band during the cutting operation?

2. Which jaw on the vise adjusts automatically to the angle setting of the other?

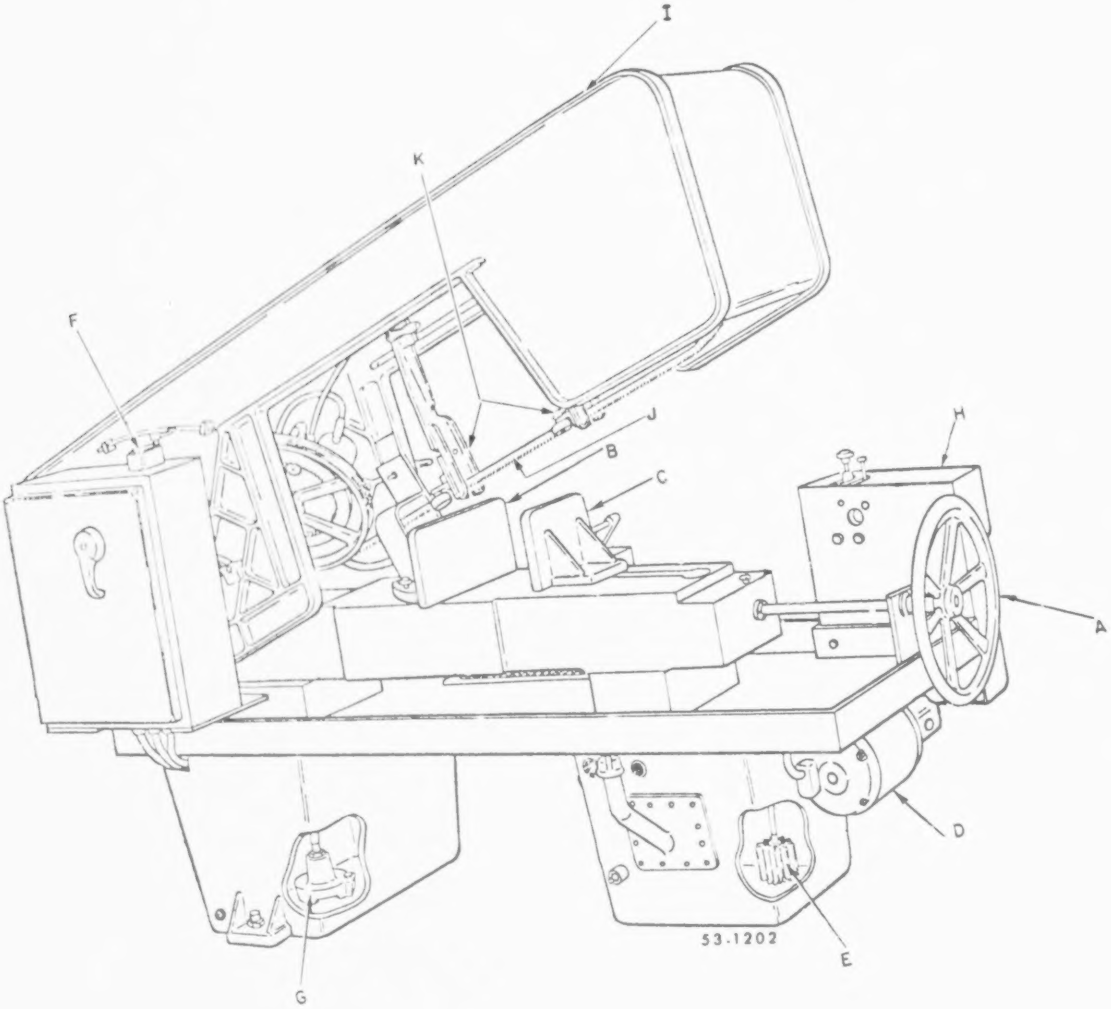
3. What is the purpose of the hydraulic pump and reservoir on the band cutoff saw?

4. What can you do after each use of the cutoff saw to help assure its continued efficient operation?

5. What two things should you check prior to each use of the band cutoff saw?

220. Identify the principle of operation of the abrasive cutoff saw and state the advantages and disadvantages of this saw.

Abrasive Cutoff Saw. A few Air Force machine shops are equipped with an abrasive cutoff saw,



A. Vise handwheel
B. Stationary vise jaw
C. Adjustable vise jaw
D. Hydraulic pump and motor assembly
E. Hydraulic fluid filter
F. Automatic shutoff switch
G. Coolant pump
H. Control box
I. Band support frame
J. Saw band
K. Band guides

Figure 3-2. Band cutoff saw.

similar to the one shown in figure 3-3. Instead of a blade or saw band, this machine uses a thin, flexible grinding wheel to cut through metal objects locked in the vise. The grinding wheel is fed down into the work hydraulically.

The abrasive cutoff machine has the advantage of making extremely smooth finishes on the sides of the cut. Also, it is capable of cutting through very hard materials. Generally, however, it should not be used to cut most nonferrous metals. Also, although it cuts through most metals very quickly, it usually generates more heat in the metal than do band type cutoff machines. NOTE. Be sure *all* guards are in place *before* operating this machine. If the wheel should break during a cut, pieces of it can cause serious injury if they are not contained by the guards provided for that purpose.

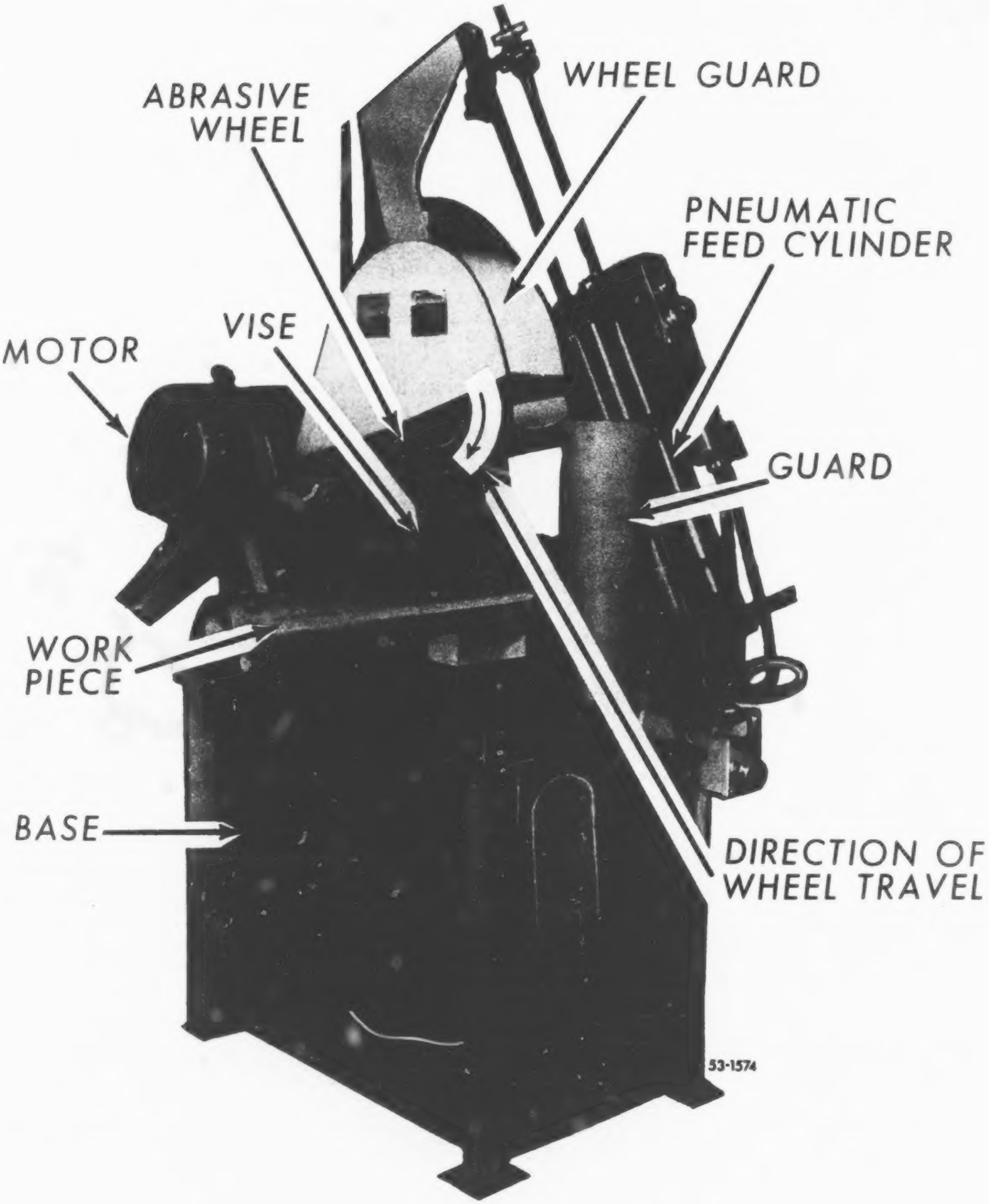

ABRASIVE WHEEL
WHEEL GUARD
PNEUMATIC FEED CYLINDER
VISE
MOTOR
GUARD
WORK PIECE
BASE
DIRECTION OF WHEEL TRAVEL
53-1574

Figure 3-3. Abrasive cutoff machine.

Exercises (220):

1. How is the cutting action accomplished on an abrasive cutoff saw?

2. List two advantages of the abrasive cutoff saw over band or blade types.

3. List one disadvantage of the abrasive cutoff saw.

3-2. Contour Machine Work

Of all the machines you will operate, the contour machine will probably be your greatest challenge to your resourcefulness and skill. Unlike the lathe and sharper, the contour machine depends almost entirely upon the skill of the operator for the precision and quality of work it produces. The contour is primarily a metal-cutting bandsaw, but you can also do filing and polishing work with it. In this section we will briefly review the parts of the contour machine – and will discuss saw, file, and polishing band terminology and selection. Also, we will discuss the setup and operation of the various bands for both external and internal operations.

221. Describe the operation and state the purpose of main parts of the contour machine.

Contour Machine. Since we will be referring to various parts of the contour machine in the next several objectives, we will briefly review the names and uses of the major parts in this objective.

Contour machines are made in a variety of sizes and models by several manufacturers. The size of a contour machine is determined by the throat depth, which is the distance from the saw band to the column. All contour machines are similar in construction and operation. In this chapter the description of the parts, the setups, and the operations pertain to one of the models that is most widely used in the Air Force. You should have no difficulty in applying the information to contour machines made by different manufacturers. Figure 3-4 will help you locate and identify the major parts.

Head. The head is the large unit at the top of the contour machine that contains the saw band idler wheel, the drive motor switch, the tension adjustment handwheel and mechanism, a flexible air line (directs a jet of air at the work to keep the layout lines free from chips) and the adjustable post which supports the upper saw guide. The job selector dial is also located on the head.

Column. The column contains the speed indicator dial which is driven by a cable from the transmission and indicates the speed in feet per minute (fpm). The butt welder is also mounted on the column. It is used to join the ends of a length saw band so that a continuous sawing edge is obtained. We will discuss the use of the butt welder more specifically in a later objective.

Base. The base contains the saw band drive wheel, the motor, and the transmission. The transmission has two speed ranges. The low range gives speeds from 50 fpm to 375 fpm. The high range gives speeds from 200 fpm to 1500 fpm. A shift lever on the back of the base can be placed in the HIGH, LOW, or NEUTRAL position. You use the NEUTRAL position when you are tracking saw and file bands manually on the guide wheel and when the machine is not in use. LOW is recommended for all speeds under 275 fpm. To shift from one range to the other, you must *always* reduce the speed to 50 fpm or less. The shift lever remains locked until the speed has been reduced. The base also supports the table and contains the lower saw band guide which is mounted immediately under the table slot. The power feed mechanism is located within the base, and feed adjustment handle and foot pedal are located on the front of the base.

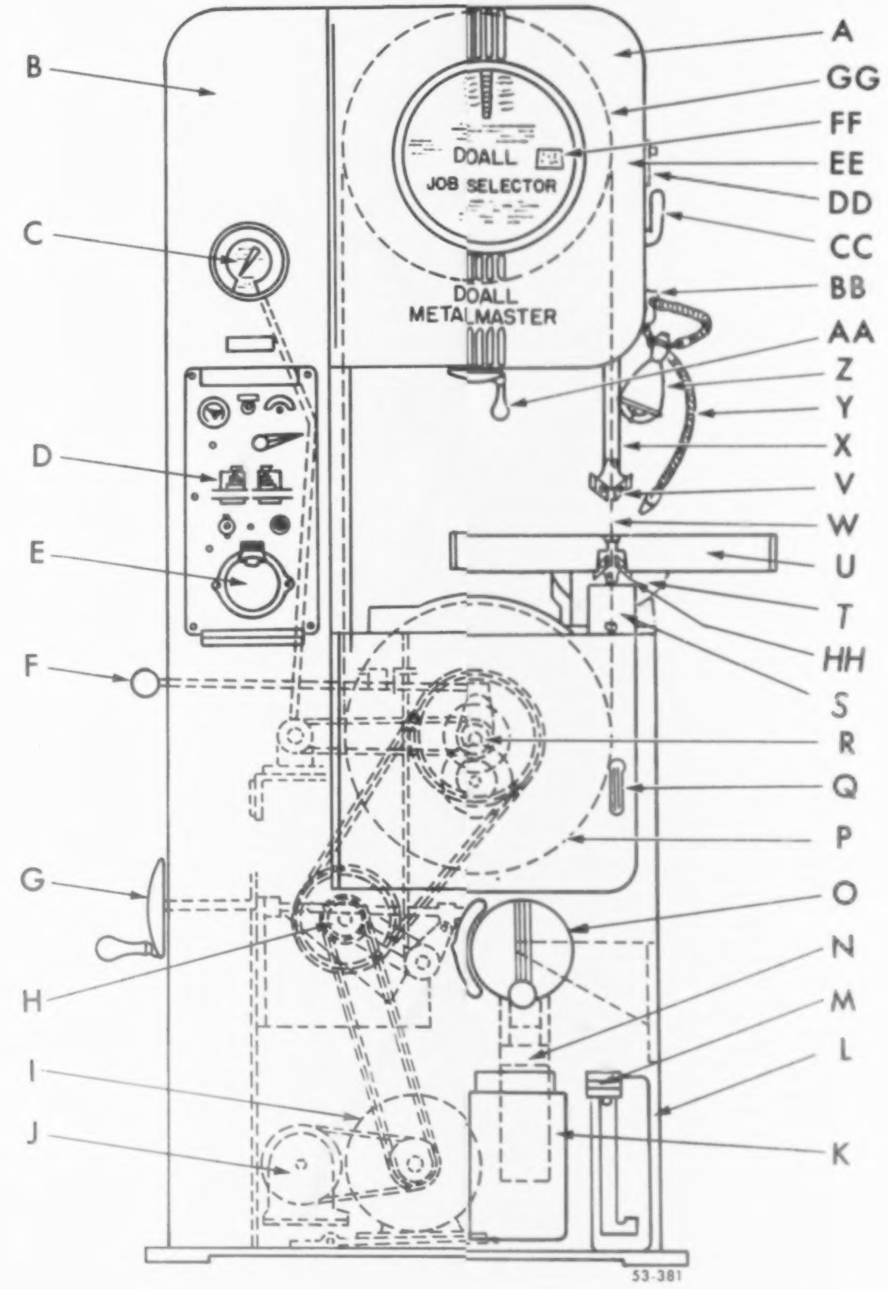
Variable speed unit. The variable speed unit is located within the base of the machine. This unit consists of two V-type pulleys which are mounted on a common bearing tube. A belt on one pulley is driven by the transmission while the belt on the other pulley drives the saw band drive wheel. The two outside cones of the pulleys are fixed, but you can shift the middle cone by turning the speed change handwheel. When you shift the middle cone, you cause the diameter of one pulley to increase and the diameter of the other pulley to decrease. This slowly changes the ratio between the two pulleys and permits you to gradually increase or decrease the speed of the machine. The variable speed unit is connected to a transmission which has high- and low-speed ranges.

Exercises (221):

Match the following contour saw parts to the corresponding functions. Some functions may be used more than once.

1. Head
2. Column
3. Base

a. Contains the tension adjustment handwheel.
b. Contains the butt welder.
c. Supports the table.
d. Contains the saw band idler wheel.
e. Contains the variable speed pulley.
f. Provides a mounting position for saw band guide and inserts.


A
B
GG
FF
EE
DD
CC
BB
AA
Z
Y
X
V
W
U
T
HH
S
R
Q
P
O
N
M
L
K
C
D
E
F
G
H
I
J
DOALL
JOB SELECTOR
DOALL
METALMASTER
53-381

A. Head
B. Column
C. Speed indicator
D. Butt welder
E. Grinder
F. Shift lever
G. Speed change handwheel
H. Variable speed unit
I. Drive motor
J. Air pump
K. Chip box
L. Base
M. Power feed foot pedal
N. Power feed weight
O. Power feed adjustment handwheel
P. Drive wheel
Q. Lower wheel door
R. Gear transmission
S. Chip baffle
T. Graduated plates for table tilt
U. Table
V. Upper saw guides
W. Saw band
X. Post
Y. Air jet
Z. Table lamp
AA. Band tension handwheel
BB. Magnifier outlet
CC. Door latch
DD. Drive motor switch
EE. Upper door
FF. Job selector
GG. Upper saw wheel
HH. Lower saw guides

Figure 3-4. Contour machine.

4. Describe the operation of the variable speed pulley.

222. Explain saw band terminology, and select proper bands for various cutting operations.

Contour Saw Bands. There is a "best" saw band for every sawing job. You must know the various features of a saw band and the types that are available in order to select the proper saw band for a given job. Following is a brief explanation of the various saw band terms.

Saw band terms. You must be thoroughly familiar with saw band terms in order to select the correct saw band. Figure 3-5 illustrates some of the common terms. We will briefly review some important saw band terms:

- Type. The type is indicated by the name of the saw band; it refers to the shape and spacing of the saw teeth.
- Teeth. The teeth are the cutting portions of the saw band.
- Gullet. The throat or opening between teeth is the gullet. It provides a chip clearance and helps remove the chips from the cut.
- Width. The width is the measurement of the band from tooth tip to the back edge of the band.
- Gage. The thickness of the band back is the gage. (For saws up to ½ inch wide, the gage is usually 0.025 inch.)
- Pitch. The pitch is the number of teeth per inch.
- Set. The set is the amount of bend given the teeth. The set makes it possible for a saw to cut a kerf or slot wider than the thickness of the band back (gage), thus providing side clearance.
- Set pattern. This is the pattern of the teeth, depending upon the manner in which the teeth are set. There are three set patterns: (1) raker, (2) wave, and (3) straight, as shown in figure 3-6.

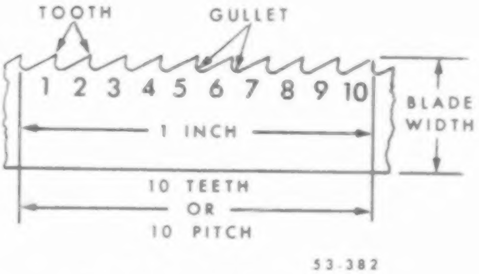


Figure 3-5. Saw band terms.

- Temper. Temper refers to the hardness of the teeth and the band. Manufacturers provide different types of bands to meet various sawing requirements. Each type of band has a temper peculiar to that type. The job selectors on the earlier contour machines recommended different tempers for various metals and materials. The present practice is to recommend a particular type of saw band for a given metal or material.
- Kerf. The kerf is the slot produced by the saw band. The kerf width depends upon the rate of feed and the saw pitch, in addition to the amount of set. Since the kerf consists of a series of grooves, the distance between the grooves varies with the pitch and rate of feed. As the distance between the grooves increases, the peaks become higher. The result is a narrower slot or kerf. The corners of the saw teeth cut a groove equal to the measurement over the set, but the kerf width is the distance between the peaks, as shown in figure 3-7.

Types. Several types of saw bands with different tempers and differently shaped teeth are made by various manufacturers. Figure 3-8 will help you recognize some of the common shapes of saw band teeth. Give special attention to the shape and spacing of the saw teeth, since they will help you to identify the various types.

Selection. The following factors should be taken into consideration when you determine the saw band to use:

- At least two teeth should be in contact with the work at all times.
- Thicker material requires fewer teeth per inch. This varies, however, with the type of material and saw speed.
- Always use the widest and thickest saw possible. However, take into consideration the curvature of the cut since, as shown in figure 3-9, you cannot saw sharp curves with wide saw bands.
- Use the raker set pattern for general sawing of most shapes.
- Use the wave set pattern where thin work sections are encountered during the cut, such as tubing, angles, channels, etc. Use it also for tough materials, such as aluminum, bronze, and work-hardened stainless steel. The wave set is designed so that the band "dances" through the kerf to shake off the chip and minimize chip welding.
- The finish depends largely on the saw pitch.

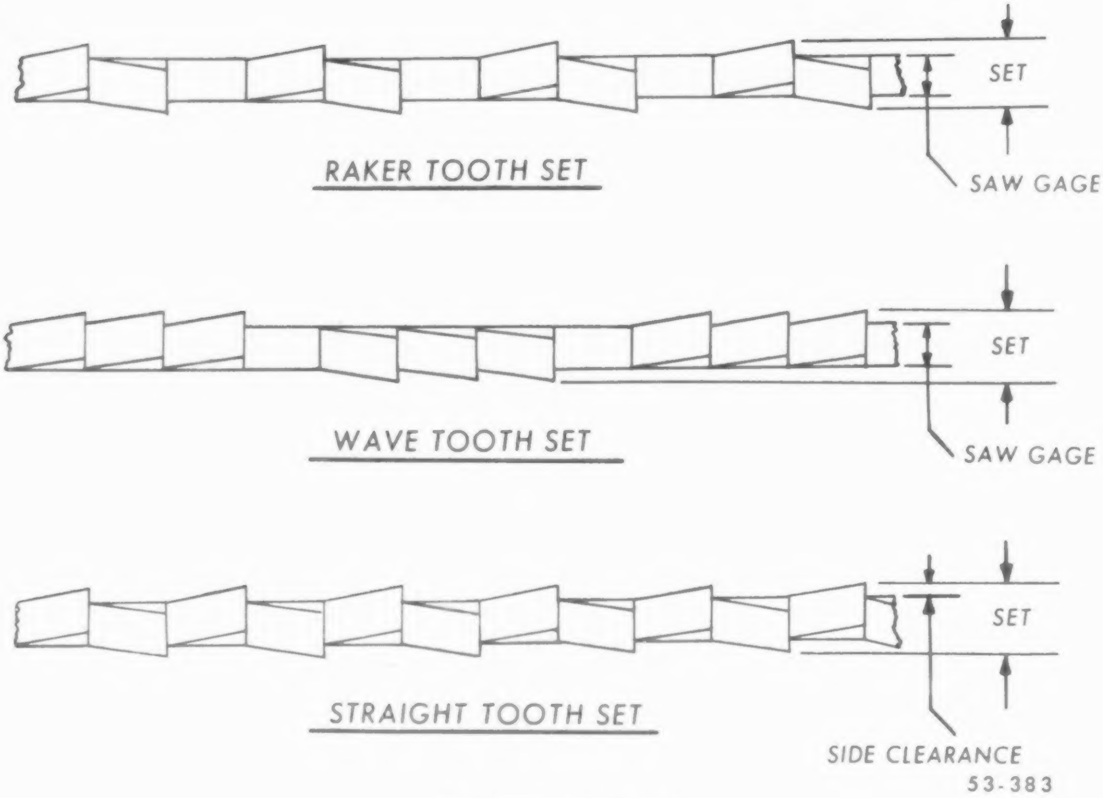

SET
SAW GAGE
RAKER TOOTH SET
SET
SAW GAGE
WAVE TOOTH SET
SET
STRAIGHT TOOTH SET
SIDE CLEARANCE
53-383

Figure 3-6. Set patterns.

The faster the saw speed and the finer the saw pitch, the finer the finish. Lubricating helps to improve the finish. A fine saw pitch, high velocity, and light feed produce the finest finish.

- Too fine a saw pitch for the work thickness causes a loading action in the gullets of the saw teeth. A lubricant will help correct this, but it is best to use the coarest pitch that will give the finish desired.
- For materials that are tough and stringy, such as brass, copper, and wrought iron, it is

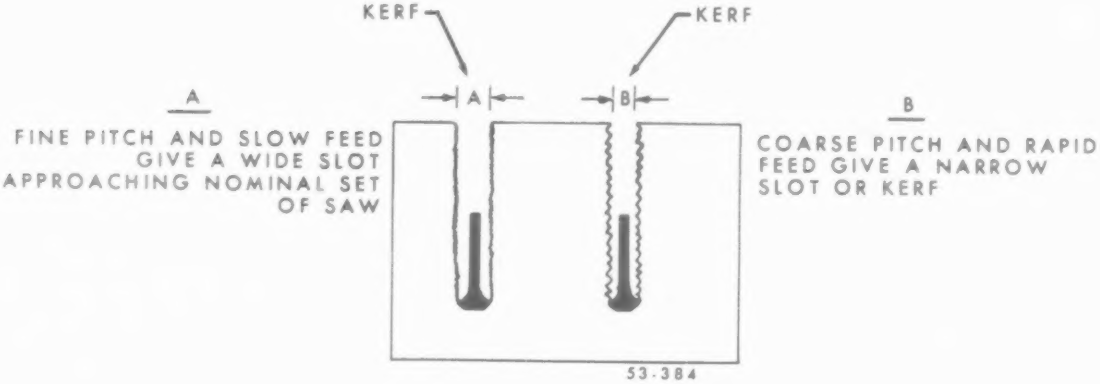

KERF
KERF
A
FINE PITCH AND SLOW FEED GIVE A WIDE SLOT APPROACHING NOMINAL SET OF SAW
A
B
B
COARSE PITCH AND RAPID FEED GIVE A NARROW SLOT OR KERF
53-384

Figure 3-7. Saw kerf.

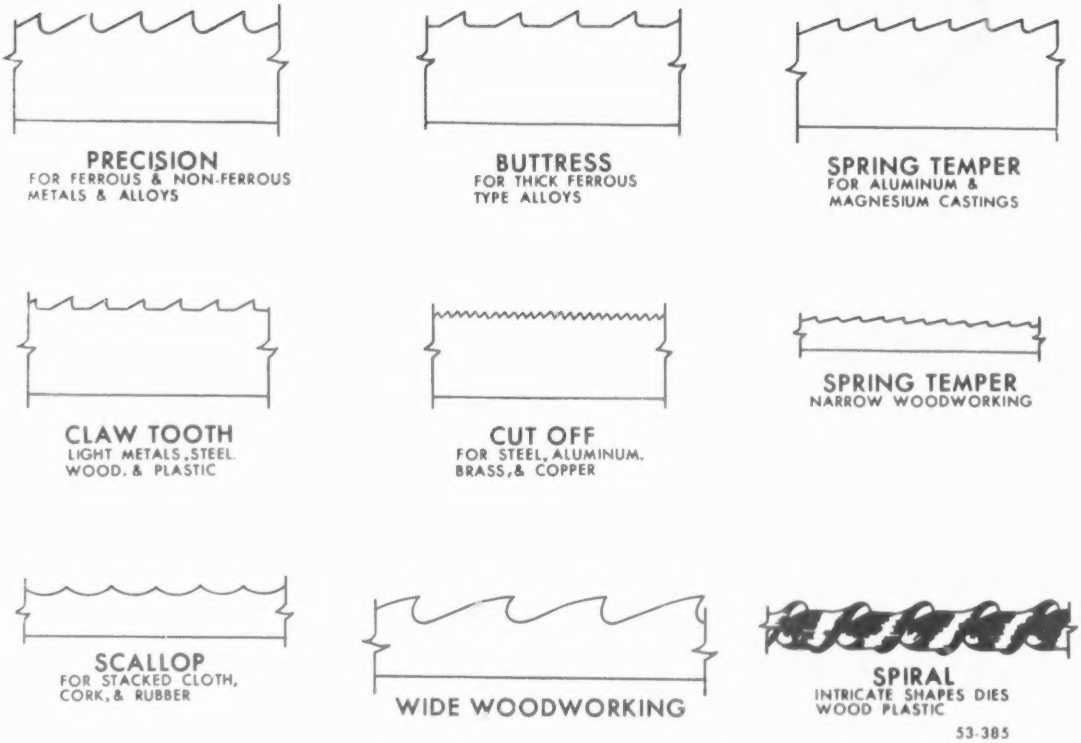

PRECISION
FOR FERROUS & NON-FERROUS METALS & ALLOYS
BUTTRESS
FOR THICK FERROUS TYPE ALLOYS
SPRING TEMPER
FOR ALUMINUM & MAGNESIUM CASTINGS
CLAW TOOTH
LIGHT METALS, STEEL. WOOD, & PLASTIC
CUT OFF
FOR STEEL, ALUMINUM, BRASS, & COPPER
SPRING TEMPER
NARROW WOODWORKING
SCALLOP
FOR STACKED CLOTH, CORK, & RUBBER
WIDE WOODWORKING
SPIRAL
INTRICATE SHAPES DIES WOOD PLASTIC
53-385

Figure 3-8. Shapes of saw band teeth.

best to use coarse-tooth bands. Fine-tooth bands are better for harder, less stringy materials and steel.

- The set prevents the band from binding. It provides a clearance which makes radius cutting possible. It is the difference between the set of the saw and the gage that enables the band to turn in a cut, as shown in figure 3-9. The amount of set determines the width of the kerf and the amount of material removed by the band. The narrower the kerf, the less feed pressure and the less power will be required for sawing.

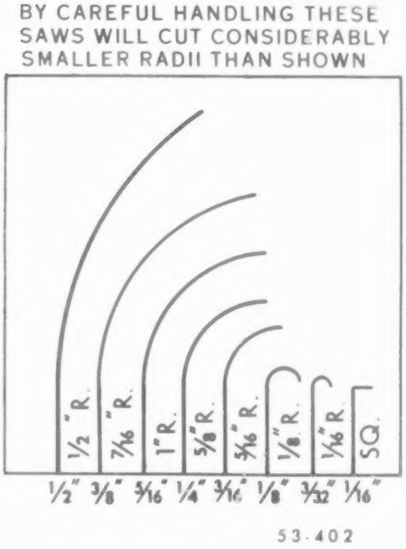
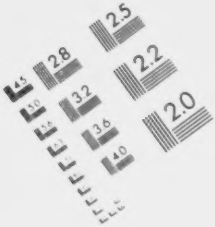

BY CAREFUL HANDLING THESE SAWS WILL CUT CONSIDERABLY SMALLER RADII THAN SHOWN
1/2" R.
7/16" R.
1" R.
5/8" R.
5/16" R.
1/8" R.
1/16" R.
SQ.
1/2"
3/8"
5/16"
1/4"
3/16"
1/8"
3/32"
1/16"
53-402

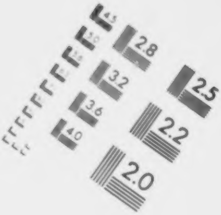
Figure 3-9. Saw band selection for various radii.

- When you cut irregular shapes you must consider the set. The wider the set, the wider the kerf and the easier it is to saw irregular shapes, since the band has more clearance in which to be turned.
- For very gummy materials, a coarse-tooth band should be used.
- The recommended pitch for various types of material is given below:

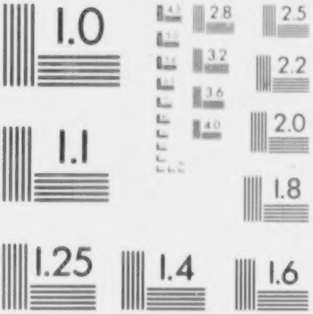
Pitch	*Material*
8	Large solid sections over 2 inches thick.
10	Soft metals.
12	Medium solid sections, ½ to 2 inches thick, and hard steels.
14	Heavy gage structurals and general-purpose cutting.
18	Light sections, 1/16 to ½ inch thick, light structurals, and medium gage sheets and tubing.



2.5
2.8
2.2
4.5
3.2
5.0
2.0
5.6
3.6
4.0



4.5
5.0
2.8
3.2
2.5
3.6
4.0
2.2
2.0



1.0
4.5
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890

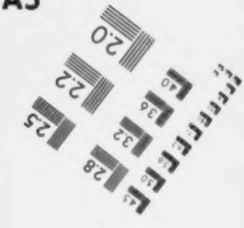
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

1.0 mm

1.5 mm

2.0 mm

A5



2.0
2.2
4.0
2.5
3.6
3.2
2.8
5.0
4.5

4.0
2.0
3.6
3.2
5.0
2.2
2.8
4.5
2.5

22	Very light sections.
24	Very light structurals, and thin gage sheets and tubing.
32	Very thin sheets and tubing.

Exercises (222):
Match the following saw band terms with the correct meaning. Some meanings may be used more than once.

1. Gullet ____
2. Gage ____
3. Set ____
4. Width ____
5. Raker ____
6. Wave ____
7. Temper ____
8. Pitch ____

a. A particular set pattern.
b. The amount of bend given the teeth.
c. The hardness of the band.
d. The thickness of the band back.
e. The opening between the teeth.
f. The number of teeth per inch.
g. The measurement from the tooth tip to the back of the band.

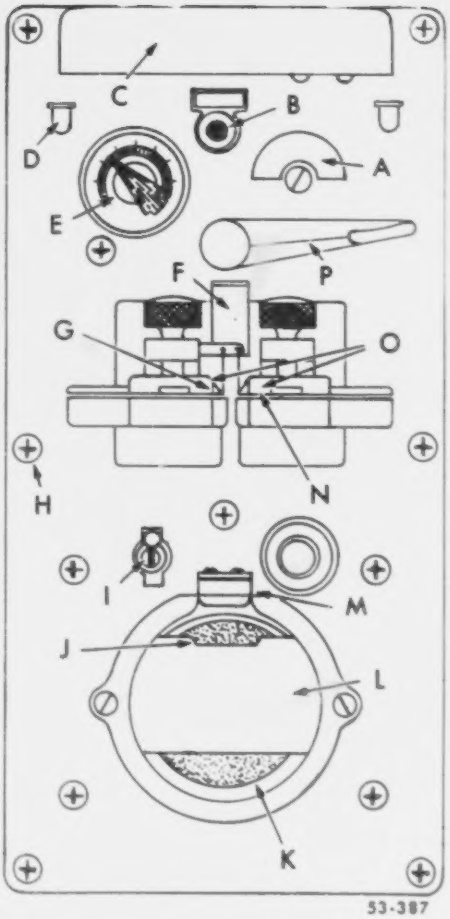
9. To assure ease in cutting irregular shapes, what part of the saw band should you give your most consideration to?

10. If you were told to order a good general-purpose roll of saw band, what pitch should you choose?

223. Describe the process of welding saw bands with the butt welder, and analyze the safety precautions involved.

Butt Welder Operation. Saw bands are usually received in the shop in coiled 100-foot-long lengths. They must be cut to the required length, and then the ends must be welded together to form an endless loop. The butt welder is used for this purpose. Figure 3-10 shows the general arrangement of the panel as viewed by the operator.

To weld a saw band, first cut off the band to the required length and follow this procedure:



A. Line voltage regulator
B. Etching pencil ground bushing
C. Lamp
D. Oil cups (for grinder)
E. Tension control
F. Flash guard
G. Stationary jaw
H. Mounting screws
I. Lamp and grinder switch
J. Step for squaring saw bands
K. Grinding wheel
L. Grinding wheel
L. Grinding wheel guard
M. Weld thickness gage
N. Movable jaw
O. Welder jaws
P. Welding operating lever

Figure 3-10. Butt welder.

- Always cut the band from the back toward the teeth because the teeth and a small area behind them is hardened. Also, align the alt so that it passes through a gullet and not a tooth. Grind the ends of the band square against the side of the grinding wheel. Then insert the ends of the band into the jaws of the butt welder with the teeth pointed toward you, and clamp them in this position by turning the thumb screws. Allow 1/64 to 1/32

between the ends of the band. Set the tension control switch for the width of band and the line voltage regulator for the required welding heat. After placing the flashguard down, depress the operating lever to complete the weld and hold it down until the weld has cooled. BEFORE releasing the operating lever, loosen the stationary jaw thumbscrew, and then release the band from the movable jaws. Move the band forward (toward the operator) to the wide gap annealing position. Reclamp the band just behind the saw teeth, with the newly welded joint centered between the jaws. Now press the annealing switch button until the welded area becomes a dull cherry red.
Turn off the welding panel light so that the correct annealing heat can be observed. Cool the annealed portion gradually by pressing the annealing button several times during the cooling period. After it has cooled enough to be safely handled, remove the band from the jaws and grind the excess weld off both sides of the band. Grind until the welded joint is the same thickness as the band. Use the gage directly above the grinding wheel to check for correct thickness. It is a good idea to re-anneal the band after grinding to relieve stresses set up during grinding.

When you weld saw bands, you should *always* wear safety goggles since the grinding wheel must be used during the welding process. Another safety precaution to keep in mind is that you should not touch the welded portion of the saw band even after it "looks" like it is cool. That area of the band will retain enough heat to cause a painful burn for several minutes after the welding has been completed. Most burns are the result of not paying attention to the welded area during the installation of the band on the drive and idler wheels.

Exercises (223):

1. Describe the way in which a length of saw band should be cut prior to welding.

2. Rearrange the following steps in the order in which they should be accomplished during a bond welding process when the band is already locked in the jaws.

_____ a. Move band to annealing position and clamp.

_____ b. Place flash geared down.

_____ c. Depress welding operator lever.

_____ d. Set tension control and voltage.

_____ e. Release welding operator lever.

_____ f. Loosen band from stationary jaw.

_____ g. Turn off welding light.

_____ h. Loosen band from movable jaw.

_____ i. Anneal to dull cherry red.

_____ j. Check thickness in gage.

_____ k. Re-anneal to relieve stress.

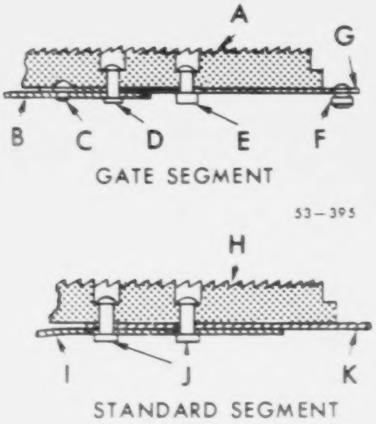
_____ l. Remove from clamps and grind smooth.

3. Describe two safety precautions that should be observed during a welding process.

224. Describe the construction and use of file band parts, and select proper file bands for various filing operations.

File Bands. File bands are available in ¼ inch, ⅜ inch, and ½ inch widths and in a flat, half-round, or wide oval shape. The shape of the work determines the shape of the file band to be used. The widest file band that will fit the contour of the work is the best rule in regard to width selection. This cuts down the filing time and also increases the life of the file band.

The band is made up of several parts or *segments* which are riveted at one end (the leading end) to a spring steel band. The trailing end of each segment is free to lift during the time when the bands bends over the drive and idler wheels of the contour saw. When the band straightens out, the segments lock together. Figure 3-11 shows the construction of and terminology for file band parts. Note that the *gate segment* (a segment at one end of the band that is specially designed to allow the two band ends to be locked together) has a shoulder rivet and a dowel rivet protruding from beneath it. The shoulder rivet locks into the other file band end and the dowel rivet aligns the two end segments



A. Yellow gate end segment
B. Steel band
C. Standard rivet (clipped)
D. Standard rivet
E. Dowel rivet
F. Shoulder rivet
G. Gate clip
H. Regular segment
I. Steel band
J. Standard rivets
K. Spacers

Figure 3-11. File band construction.

and prevents the shoulder rivet from sliding out of the locked position during a filing operation. The gate segment of a file band is identified by yellow paint. File bands can be easily repaired if the band should break. Figure 3-12 shows the step by step procedure for making such repairs.

Selecting the proper file band cut for a particular material or operation is very similar to selecting a common file. File bands are either coarse or bastard cut and normally range in pitch from 10 to 20 teeth. The coarse cut, 10-pitch bands are used for cutting softer metals such as aluminum, brass, copper, cast iron, and etc. A bastard cut, 14-pitch band is a good choice general steel filing operations, while 16- to 20-pitch bastards are recommended for tool steels.

Exercises (224):

1. Describe way in which the two ends of a file band lock together.

2. What type of file band should you select to file a ½-inch convex radius and several flat areas on a piece of tool steel?

225. Select polishing bands for various operations, and explain the setup procedures.

Polishing Bands. The standard polishing bands are 1 inch wide and are available in the following grit sizes:

Application	*Grit*
Grinding	50
Polishing, coarse	80
Polishing, fine	150

Polishing bands are in the form of a loop when they are received in the shop. You mount and track a polishing band in a manner similar to that used in mounting and tracking a saw or file band. Mount the polishing band guide on the guidepost and fasten the polishing guide support to the keeper block, as shown in figure 3-13. To prevent tearing, the polishing band must be mounted on the two wheels in a definite manner. There is an arrow mark on the back side of each band. When you place the band over the wheels properly, the arrow points in the direction in which the band travels. Proper mounting prevents the ends of the band, which are overlapped and glued, from separating. Too much work pressure will cause the edges of the band to fray. Remove any frayed edges immediately to prevent the band from tearing and possibly injuring you. Also, the application graphite powder to the band guide to lubricate the band.

The recommended speeds for polishing are somewhat higher than the speed range of most contour machines. The polishing speed depends upon the grit size of the polishing band. The coarser the grit, the slower the surface foot speed of the band should be. The speed for polishing various metals can be found in operating manuals or in machinists publications, such as the *Machinery's Handbook*.

Tension for polishing bands should be just "snug" enough to eliminate slippage. Too much tension will stretch and possibly tear a band. The guide support, which acts as a backing for the polishing band when work is being polished, should be supported at the lower end. The lower end of the band polishing guide does not, however, get any support from the guide support until the post is lowered to a position of 4 inches or less, as marked on the guidepost.

Exercises (225):

1. What polishing band should you select to produce a smooth finish on the sides of blanking die?

2. Explain where the polishing band guide and the guide support are mounted on the contour machine.

226. Explain setup procedures for saw bands.

Saw Band Setup. To setup a saw band, you must first prepare the saw guide *inserts* for the size band

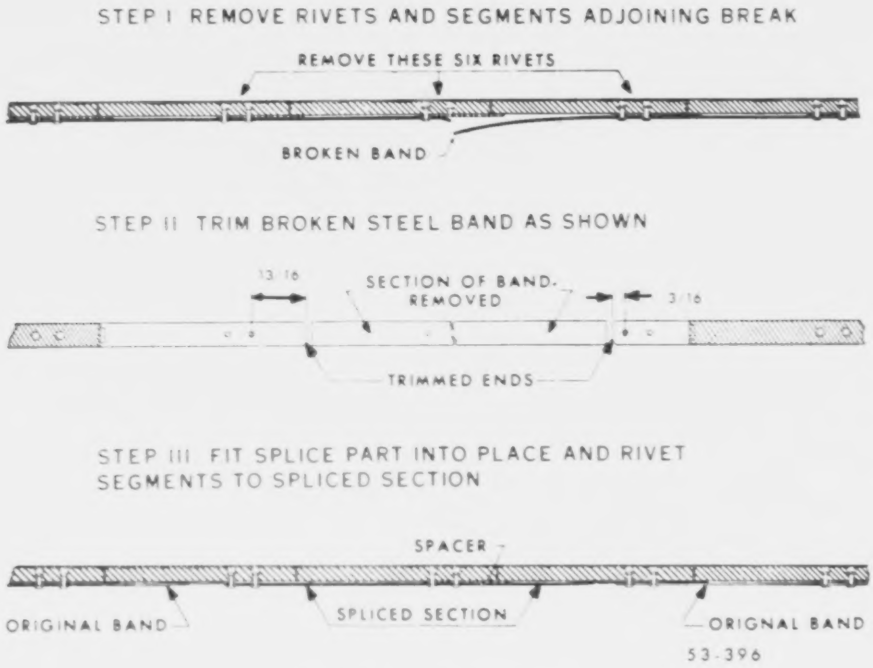
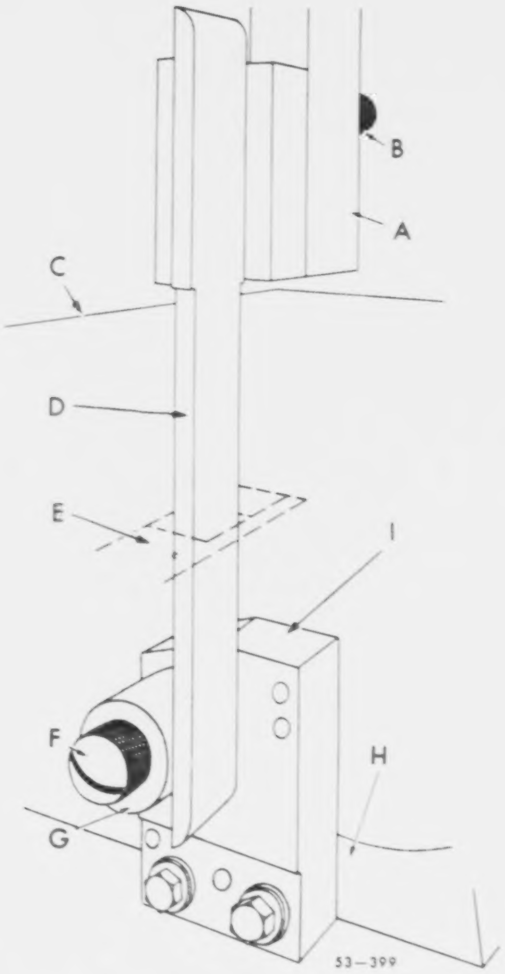

STEP I REMOVE RIVETS AND SEGMENTS ADJOINING BREAK
REMOVE THESE SIX RIVETS
BROKEN BAND
STEP II TRIM BROKEN STEEL BAND AS SHOWN
13/16
SECTION OF BAND REMOVED
3/16
TRIMMED ENDS
STEP III FIT SPLICE PART INTO PLACE AND RIVET SEGMENTS TO SPLICED SECTION
SPACER
ORIGINAL BAND
SPLICED SECTION
ORIGNAL BAND
53-396

Figure 3-12. File band repair.

you will be using. Inserts are provided for each width of band, and failure to use the correct insert can cause damage to the band and the inserts. The inserts should be centered on guide blocks (as shown in figure 3-13) with one of three gages, depending on the width of the saw band. It is especially important to allow sufficient clearance between the inserts for the band and at the same time to prevent the band from wobbling or moving from side to side. Therefore, even though it is tempting to locate the inserts by sight, it is always best to use the gage. When the ends of the inserts become worn, they can be reground to an angle of 45°. After the inserts have been installed on the guide blocks, the guide blocks can be mounted in the machine. The upper block mounts to the lower end of the guide post and is secured by two thumb screws which pass through the guide post and screw into the guide block. The lower guide block mounts to a keeper block just below the table. It is secured by one screw which passes through the guide block and screws into the keeper block and is aligned by a dowel pin located in the keeper block. The locations of the insert assemblies can be seen in figure 3-14.

Band mounting. After the inserts have been properly installed in the machine, the saw band can be mounted. NOTE: *The transmission should be in* NEUTRAL *so that the wheels can be turned by hand*. After opening the upper and lower wheel access doors and removing the table filler bar, place the right-hand portion of the saw band in the table slot, and position the saw band over the upper wheel and below the drive wheel. Set the tension by using the handwheel, shown in figure 3-15,J, just tight enough to keep the band on the wheels. Then check to insure that the saw band is positioned between both the upper and lower sets of inserts. Rotate the upper wheels by hand, and check to insure that the back of the saw band rides on the thrust roller on each guide block. If it does not, you will have to adjust the upper wheel in the following manner. After loosening the tile locknut (figure 3-15,F), rotate the upper wheel by hand and use the tilt screw (figure 3-15,G) to tilt the upper wheel until the back edge of the saw band contacts the thrust roller on the guide block. The moving band should cause the roller to turn, but light finger pressure should stop the roller from turning. Once the band is tracking (moving between the inserts and rotating the thrust roller) correctly, lock the tilting wheel by means of the tilt locknut.

The next thing to do is set the tension on the saw band by raising or lowering the upper wheel by means of the handwheel, shown in figure 3-15,J. The saw band must be kept tight to prevent it from twisting and to keep it sawing straight. A new saw band will stretch slightly after use and must be readjusted for the proper tension. There is no hard-and-fast rule governing the tension adjustment. You must rely on your experience to guide you. Generally speaking, it is better to have the band too tight than too loose. NOTE: Overtightening the saw band can cause it to break or



A. Guide post
B. Polishing guide screw
C. Table
D. Polishing band guide
E. Filler plate
F. Support screw
G. Polishing guide support
H. Trunnion cradle
I. Trunnion keeper block

Figure 3-13. Polishing band guide.

cause excessive wear on the wheel tires. Extra care should be used when you adjust the tension of bands less than 3/16 inch in width.

Finally, replace the table filler bar and close the upper and lower wheel doors. *NEVER attempt to operate the saw with either of these two doors open.* At this point the transmission may be put in gear, and the saw may be operated by power.

Exercises (226):

1. Explain how both guide blocks are secured and state where they are mounted on the contour machine.

2. Explain how to adjust the upper wheel to cause the band to track properly.

3. When setting the tension on a saw band, how tight should you make it?

227. Explain the setup procedures for file bands.

File Band Setup. Just as with saw band setups, the first thing to do is to place the transmission in neutral, and *then* open the access doors and remove the table filler bar. Next, the file guide and file guide support must be installed. Figure 3-16 shows a file guide assembly installation. The file guide aligns and supports the file band at the point of contact with the work and must conform to the width of the file band. It is mounted on the guide post. The lower end of the file guide rests on the file guide support (figure 3-16,G) which is attached to the trunnion keeper block by a thumbscrew. The file guide support has three different width slots or *channels* ($\frac{1}{4}$ inch, $\frac{3}{8}$ inch, $\frac{1}{2}$ inch) around its circumference and you must be sure to align the proper size slot behind the file guide.

Now the file band can be installed. You should handle file bands with care if you are to prevent kinking the spring steel band. A kink prevents the segments at the location of the kink from interlocking, causing rough, uneven filing. When you carry a file band, hold it with both hands and form a loop with no less than a 16-inch radius at the top. Support the file band over one shoulder when you connect the gate segment just prior to putting the band over the upper wheel, secure it with one hand, and lower the upper wheel until the band will slip easily under the lower wheel. Be sure the band is seated in the file guide, and then gently apply tension with the tension handwheel. The tension setting for the file should be approximately the same as for a saw band of equal width. Once the tension is set and you have rotated the upper wheel by hand to check the tracking of the band, you can close the access doors and install the table filler bar (if available, use a bar designed for use with the file band; the filler bar for saw bands cannot be completely inserted when used with a file band). Now you're ready to put the machine in gear and adjust it for the proper speed. In our next objective, we will discuss cutting speeds and feeds for both sawing and filing.

Exercises (227):

1. When you are preparing to set up a file band, what should you do before opening the access doors?

2. Explain where the file guide and the guide support are mounted and how they work.

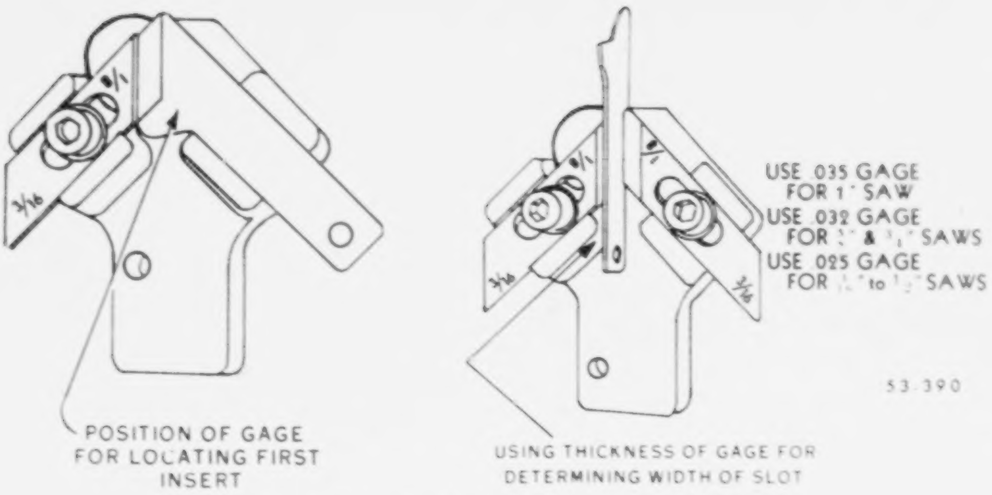
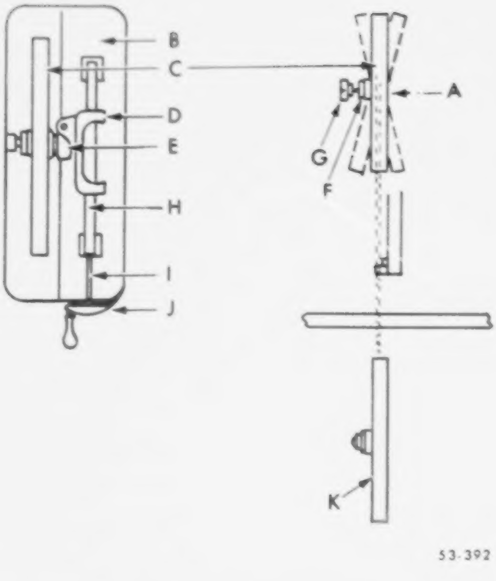

3/16
1/16
POSITION OF GAGE FOR LOCATING FIRST INSERT
USING THICKNESS OF GAGE FOR DETERMINING WIDTH OF SLOT
USE .035 GAGE FOR 1" SAW
USE .032 GAGE FOR [illegible] & [illegible] SAWS
USE .025 GAGE FOR [illegible] to [illegible] SAWS
53-390

Figure 3-14. Installation of saw guide inserts.

3. What is the smallest radius or bend that a file band should be subjected to and why?



A. Upper wheel and adjustment assembly
B. Upper door
C. Upper guide wheel
D. Slide
E. Hinge
F. Tilt locknut
G. Tilt screw
H. Slide rods
I. Slide screw
J. Handwheel
K. Lower (drive) wheel

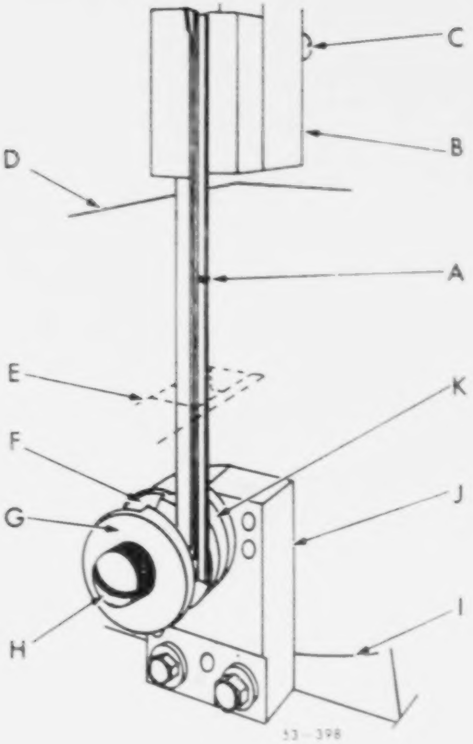
Figure 3-15. Tilting wheel.

228. Select correct speeds and feeds for sawing and filing various materials.

Speeds. The speed of saw bands and file bands is given in feet per minute from the number of feet of band that passes the work in one minute. When selecting the speed for a sawing operation, you must consider the thickness of the material to be cut as well as the type of material. Most contour machines are equipped with a job selector dial (figure 3-4,FF), which specifies recommended speeds for specific saw and file bands based on the type and size of work to be cut or filed. The job selector dial is the best source for recommended speeds for most operations.

When a job selector dial is not available, you can find general speed recommendations in the operator's manual or in machinist publications such as the *Machinery's Handbook*. Normally the nonferrous metals should be sawed at higher speeds (700-1500 fpm) depending on the thickness of the material. Titanium and monel are notable exceptions; they should be sawed at much slower speeds (90-125 fpm). Carbon steels require 100-150 fpm while cold-rolled steels require 150-200 fpm. The speed for filing is always much slower than that for sawing and will normally be done with the transmission in low range only. Filing on nonferrous metals can be done at faster speeds than on ferrous metals, but it should not be necessary to operate the file bands any faster than 250 feet per minute.

Feeds. There is no specific rate of feed when the work is fed into the saw band by hand. Usually,



A. File guide
B. Guidepost
C. File guide screw
D. Table
E. Filler plate
F. Channel for 1/2" guide
G. File guide support
H. Support screw
I. Trunnion cradle
J. Trunnion keeper block
K. Channel for 1/4" guide

Figure 3-16. File guide assembly.

medium pressure will suffice for sawing operations, but on metals that do not dissipate heat rapidly, such as titanium, a heavy feed pressure is best. Be sure that the guide post with the guide inserts is lowered to within 1/8-3/8 inch of the work whenever possible to provide maximum support for the band when the work is being fed into it. Also, you should always use a pusher block instead of your hands to guide and feed work when the power feed attachment is not used. A pusher block can be just about anything that will keep your hands back away from the work and saw band. If you try to feed the work without a pusher block, you run the risk of burning your fingers, since the part will usually become quite hot during the sawing operation. Also, as you near the end of the cut, it is extremely easy to get your fingers in the way as the band breaks through the edge of the material. The use of the power feed attachment will be discussed in a later objective.

The feed pressure for filing depends on how much material is to be removed and the finish required. Since the coarse bands are usually used to remove larger amounts of material, they normally require heavier feed pressure. As the need for better finishes increases, the feed pressure is decreased.

Exercises (228):

1. To properly select the correct speed for a sawing operation, what two things must be considered?

2. How does the recommended speed for sawing titanium and monel differ from that of most other nonferrous metals?

3. What should normally be the maximum fpm for any file band operation?

4. Why should the sawing feed pressure be greater on titanium than on most metals?

5. What governs the amount of feed pressure required for a filing operation?

229. Select proper procedures for straight and contour external sawing.

Straight Sawing. The first thing to do before starting a sawing operation is to put safety glasses or goggles on. Chips produced by the contour saw are very small and they blow around easily, so be sure to protect against them.

For straight sawing you should use the widest available saw band of the proper pitch. This will help keep the band from twisting and will make the cut straighter. Thinner bands are required for contour sawing. This prevents the band from rubbing on the sides of the cut. When a sawed finish is desired, the kerf should just split the layout line on the waste side of the metal. If a filed finish is desired, approximately 1/64 inch should be allowed on the waste side of the layout line. If a corner requires a small radius, the proper size of drill to give this radius should be used. In order to cut a sharp or corner, the corner may be cut to a drilled hole first and then the radius of the corner notched out with the saw. Square turns may also be made without drilling. This is done by notching a space with the saw. The saw can then be turned on this notch and a cut can be made in another direction.

In straight sawing you should maintain a constant pressure against the work. Permitting the saw to ride without cutting dulls the saw teeth and can work harden the metal. Use a pusher block to apply pressure to the work to avoid injury to your hands. Saw band breakage during sawing is not common, but if it should occur, stand clear of the machine, press the stop switch, and let the wheels coast to a stop.

Remember, the edge of the saw kerf should split the layout line when a sawed finish is permissible, but be *sure* that the kerf is on the waste or scrap side of the layout line! Position the blower nozzle to blow the chips off the layout line and away from you.

Contour Sawing. Contour sawing is sawing to a layout line of a definite radius or irregular contour. The size of the smallest radius to be cut and the thickness of the material must be considered in selecting the saw band. As the size of the radius decreases, the width of the saw must be decreased to cut the curvature. You should use the widest saw band possible that will allow the contour to be cut. The saw band pitch and set must be suited to the thickness and kind of material to be sawed.

The widest recommended saw band for various radii is given on the job selector dial. As an example, to cut a 1½-inch radius, a ½- inch saw band is recommended, while a ¼-inch saw band is recommended for cutting a ⅝-inch radius. It is usually better to drill a hole if you want to produce radii under ½ inch; but there are saw bands which can cut a 1/16-inch radius or less.

The rule for maintaining constant pressure during the cutting operation applies for contour sawing as well as for straight sawing. It not only prolongs the band life, but also gives more control over the direction of the cut and produces a smoother finish than does a series of intermittent cuts. Also, be sure you use a pusher block.

Exercises (229):

1. In straight sawing on the contour machine, suppose you must make a 90° corner in the saw cut and a ½-inch corner radius is required. Explain how to make this cut with a ½-inch-wide saw band.

2. How can you help prevent injury to your hands when applying feed pressure to the work by hand?

3. A ½-inch-wide saw band is recommended for cutting a 1½-inch radius. Why is this considered to be the widest band suitable for cutting the 1½-inch radius?

4. Explain the advantages of constant feed pressure over intermittent pressure during straight or contour sawing.

230. Describe procedures for straight and contour internal sawing operations.

Internal Sawing. The procedure for internal sawing is essentially the same whether it is straight or contour work; however, most internal sawing can be classified as contour sawing. As in external sawing, you split the layout line if a sawed finish is sufficient, and you leave 1/64 inch for finishing if filing and polishing is required. Internal sawing differs from external sawing mainly in the preparation of the work and saw band. For instance, if you had to cut a square hole in the center of a work piece without cutting through the outer ring, you would need to make a starting place for the saw band.

Therefore the first step in internal sawing is to drill a starting hole in the waste portion of the workpiece tangent to a layout line, and drill any necessary corner holes. The starting hole must be slightly larger in diameter than the width of the saw band. The width of the saw band that you should use depends upon the size of the smallest radius to be sawed. Check the table to see if it is 90° to the post. Mount the guide blocks with the proper inserts in them. Now, insert the saw band through the starting hole and weld it together. Make sure that the teeth of the saw band are pointing *down* when it passes through the hole. Place the work on the table, with the saw band in the table groove. Install the band on the wheels. Check to insure that the band is tracking properly. Then insert the filler bar in the table groove. Turn the motor on and set the required speed. Position the air nozzle and perform the sawing.

When you have finished sawing, set the machine for its lowest speed. Place the transmission shift lever in neutral and turn the motor off. Cut the saw band weld out and remove it. This keeps the number of welds on a band to a minimum. Then remove the part and reweld the band before storing it.

Be careful when you take the saw band out of the machine after finishing the operation. It is easy to forget that part you just cut is hooked to the saw band. If it isn't supported when you pull the band out of the table slot, the part will fall to the bottom of the band, and the resultant jerk on the band can cause severe cuts on your hands. It can also kink the saw band and damage the part.

Exercises (230):

1. What is the first step in preparing for an internal sawing operation?

2. Describe the procedure for mounting the saw band for an internal sawing operation.

3. Describe the procedure for removing the finished work and saw band after an internal sawing operation.

231. Explain the procedures for external and internal filing and polishing operations with the contour machine.

External Filing and Polishing. The most important step in a filing or polishing operation is the setup of the machine. Be sure you have the file band guide and guide support for the file band you want to use. For polishing, be sure the polishing band guide and support are properly installed and lubricated.

Filing. When you file work, do not use too heavy a pressure as it will cause the file teeth to clog with chips; however, the coarse-cut bands can take heavier pressure than can the bastard-cut bands. For finish filing, a light pressure usually does the best job. Move the work slowly from side to side. This will produce vertical file marks on the file surface. If you move the work too rapidly, the file marks will be diagonal and the surface will not be as accurate or as smooth as it could be. A pusher block should be used whenever possible when filing, but, in any case, KEEP YOUR FINGERS AWAY FROM THE FILE BAND. FILE BANDS CAN PULL FINGERNAILS OUT! Also, be sure to keep the part flat on the table during filing. The tendency on taller parts is to force the top into the band harder than the bottom, which causes the surface to be angled rather than square with the table.

Polishing. The polishing operation is very similar to filing. Light pressure should be used and a slow movement from side to side. If the surface to be polished is fairly rough, you will get the job done quicker by first using a rough grit band and then a fine grit band. Trying to do the whole job with a fine grit band will wear the band out quickly and will build up unnecessary heat in the work piece.

It is just as important to keep your fingers out of the way of the polishing as it is with the file band. The polishing band can take a layer or two of skin off your finger before you realize you have touched it!

Internal Filing and Polishing. You do internal filing and polishing to finish internally sawed surfaces. File bands are made with a joint or gate segment, as previously explained. This allows threading the file band through a sawed hole and joining it into a band. When polishing bands are used, they are threaded through a sawed hole and then glued together into a band. Internal polishing is limited to certain classes of large work. The width of the band and its guide will not allow polishing small and abrupt inside curves.

The selection of file and polishing bands for internal surfaces is governed by the same factors that determine the filing and polishing of outside surfaces. You use the same speeds and procedures for internal filing and polishing as for outside operations. Some classes of internal filing and polishing operations require more manual skills and exacting procedures than for outside operations. This is because of the difficult handwork and obscured vision. Chip buildup on the table and under the work presents a constant problem and can impair accuracy.

Exercises (231):

1. Explain the best procedure to insure smooth and accurate surfaces are produced when performing a filing operation.

2. What is the best procedure to follow if you must polish a rough surface to a smooth finish with polishing bands?

3. Why is internal polishing limited to larger classes of work?

4. What special problem is present with internal filing and polishing that can easily impair accuracy if left unchecked?

3-3. Special Contour Machine Operations

The contour machine can perform many operations other than just the simpler ones already described. In this section we will discuss some of these operations, some of the attachments and their uses, and the maintenance practices for keeping the machine functioning properly.

232. Explain the procedures for setting up the contour machine for angular sawing, filing, and polishing.

Angular Work. Sawed surfaces are normally at a 90° angle to the table surface. It is sometimes necessary for the sawed surface to be at an angle other than 90°. This is true, for example, when angular clearance must be given to a punch and die. The table can be tilted forward or backward up to 10°, to the left up to 10°, and to the right up to 45°. Most contour machines have two sets of holes in the keeper block for the mounting of the lower saWhen an angle of 20° or less is to be sawed, the lower saw guide should be mounted in the upper set of holes in the keeper block. To saw an angle of more than 20°, use the lower set of holes. The lower set of holes is provided to insure that the saw guide does not limit the tilting of the table. You tilt the table by loosening lock bolts located below the table and then set it to the desired angle. The settings are indicated on graduated plates located below the table. You may check the angular setting by measuring the angle formed by the post and the tabletop with a protractor head and blade. Tighten the table lock bolts after you have positioned the table to the desired angle. From this point on angular sawing is done in the same manner as is straight and contour sawing. Feeds and speeds for angular sawing are the same as for straight and contour sawing. Both internal and external sawing can be performed.

Angular filing is done for the same purpose as for other filing operations. Selection of bands, speeds, and the setup procedures are the same as those for all filing operations. After the sawing operations, you file the work as required without disturbing the table setting. This assures that the correct finished angles will be produced. External and internal mating parts are more easily fitted if the table setting is not disturbed when each part is finished.

Exercises (232):

1. Explain how the lower saw guide is affected when the table is tilted more than 20°.

2. Explain how to check the angle of the table other than by the graduated plates below the table.

233. Analyze procedures for three-dimensional and stack sawing operations, including work preparation.

Three-Dimensional Sawing. Three-dimensional sawing, filing, or polishing are operations that produce two or more surfaces which may be at an angle to each other. You can produce many three-dimensional shapes more easily on the contour machine than on other machine tools. The reason is that on other machines you produce shapes having radii and compound angles – but you do so by a series of tooling setups on the surface of the work. On the contour machine you can cut many of the irregular shapes and angles directly. The most important factor in the sawing of a three-dimensional object is the layout prior to the actual cutting. Scribe the layout lines on two or more sides of the stock prior to cutting the irregular shapes. Use extreme care to make sure that the laesponds as to size and shape from one side to the other. You must decide the sequence of cuts necessary on each side, and the layout must correspond to this sequence. You must also decide which waste pieces can be sawed off immediately and which must be retained to support following cuts. When support and reference sides are needed, partial cuts can be made, and you can finish the cuts after the work has been completed to a point at which support and layout are no longer necessary. Surfaces that are at right angles to each other are produced by setting the work table at zero or perpendicular to the post and saw band. You can produce most other angular surfaces by tilting the table to the desired angle. The only limitation to cutting angles by tilting the table is the range of the table movement. If angular surfaces are required, the normal method is to complete one surface, such as sawing, filing, and polishing, before going to the next surface. You should use this method, unless it is not practical, because the position of the table for a given angle does not change. Finish one angular surface to specifications and then set the table for another angle.

Stack Sawing. Stack sawing is the sawing of several pieces of sheet material of the same shape in one operation, as shown in figure 3-17. This method of duplicating identical parts saves time, especially when not too many pieces are needed and when the job does not warrant the manufacture of a blanking die. The number of pieces that may be stack sawed is limited by the capacity of the machine. The capacity of the machine for sawing duplicate pieces is the same as for sawing solid material. This operation can be best applied to flat pieces of sheet stock since it is necessary to stack one piece on another. After the material has been stacked, it must be fastened together to hold it during the sawing operation. For larger work, rathern than relying on the weight of each piece for the close contact desired, it is best to place the stack in an arbor press. Holes may be drilled on the waste section of a stack and the stack bolted or welded together to hold the work for the sawing operation. Small stacks for small parts can be placed in a vise and fastened together by soldering. You must decide from the nature of the work which method is best suited for fastening the pieces together. If bolts are used, the heads may interfere and not allow the workpiece to lay flat on the machine table. The heads should be countersunk flush with the bottom piece of work to prevent chatter. (NOTE: Keep the thickness of the stack in proportion to the size of the base so that it will not become top heavy, difficult to handle, or dangerous to the operator.) The thickness of the stack should be no greater than the width.

Exercises (233):

1. What are the two most important steps in preparing work for three-dimensional sawing?

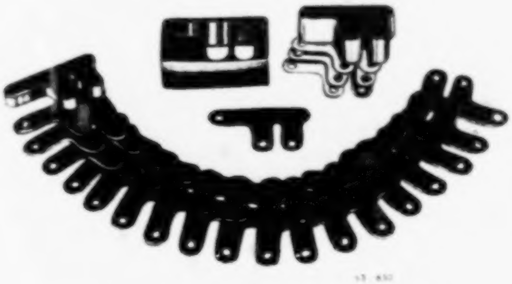


Figure 3-17. Stack sawed parts.

2. What must be considered before cutting away waste pieces from a three-dimensional sawing operation?

3. Explain three ways in which metal pieces can be held together for a stack sawing operation.

4. What problem can occur during a stack sawing operation if the stack of pieces is too tall in proportion to its base?

234. Explain the purpose of friction sawing and the setup procedures involved.

Friction Sawing. Friction sawing can only be used to saw hardened steels. This method of sawing makes use of the heat generated by friction. The heat generated by the contact between the saw band and the work is concentrated on the workpiece faster than it can be absorbed. The high temperature softens the metal, and the saw teeth scoop the heated metal away from the work. The temperature generated at the point of contact exceeds the red heat temperature, but is below 1600° F. The saw band does not overheat because of the limited time that a given portion of the band is in contact with the work. The teeth are air cooled before they reenter the cut. Dull saw bands friction-saw better than sharp ones. Dull teeth increase the friction, generate a higher temperature, and permit the material to be removed faster. The bands should be installed with the teeth upside down as this will increase friction, generate more heat and prevent the teeth from tearing off the band.

In friction sawing you use a fairly heavy feed pressure in conjunction with a high velocity of the saw band, from about 7000 SFS to about 14,000 SFS, depending upon the material being cut. This requirement for such high cutting speeds prevents the use of the standard contour machine for efficient friction sawing, although it can be accomplished with some difficulty. It should be done only on a machine capable of producing the high velocity needed – a heavy-duty type which usually uses the roller-type saw guide insert. Never use this method to saw combustible materials.

Exercises (234):

1. What is the purpose of friction sawing?

2. Explain how the saw band should be selected and mounted for friction sawing.

3. What is the recommended speed range for efficient friction sawing?

235. Describe the power feed attachment and its operation.

Power Feed Attachment. The power feed attachment, shown in figure 3-18, permits you to use both hands to guide the work. The power is provided by a weight on a beam. The location of the weight on the beam determines the rate of feed and the pressure which is exerted on the saw band by the work. You vary the location of the weight by turning the power feed handwheel on the front of the machine. Turning the handwheel clockwise reduces the pressure and the rate of feed. Turning it counterclockwise increases the rate of feed. When the handwheel is in the extreme counterclockwise position, the weight exerts a pressure or pull of 60 to 75 pounds. The pressure is transmitted to the work by means of a cable and chain, as shown in figure 3-18. Position the movable pulleys in line with the sides of the work for straight sawing and slightly outside the edges of the work for contour sawing. NOTE: You can use the workholding jaw, shown in figure 3-18, to hold the work. Place the power feed chain around it as shown in figure 3-18.

You engage the power feed by releasing the foot pedal. Unlock the foot pedal by depressing it and moving it slightly to the left. Do not allow the foot pedal to rise too rapidly, or the work may be jerked into the saw band. Disengage the power feed by depressing the foot pedal when you are approaching the end of the cut.

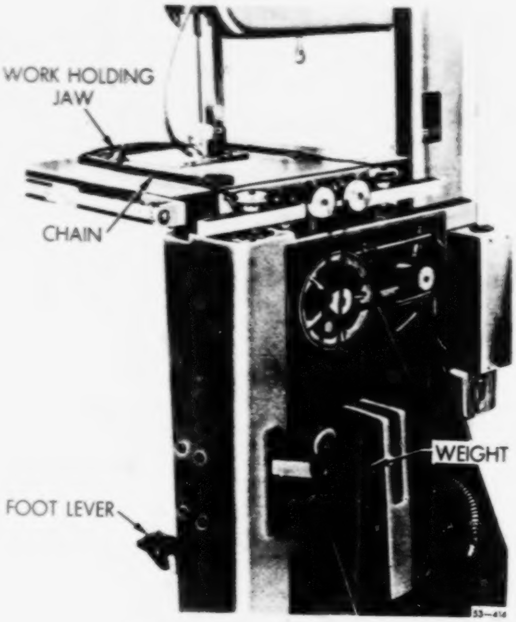


Figure 3-18. Power feed.

Exercises (235):

1. Describe how the "power" is provided by the power feed attachment.

2. How is the pressure or pull of the power feed attachment transmitted to the work?

3. Describe how to set and engage the power feed.

236. Describe the magnifying attachment and the disc-cutting attachment, and explain the purpose and use of each.

Magnifying Attachment. The magnifying attachment, shown in figure 3-19, consists of a 3-inch rectangular lens mounted in a flanged housing. The housing contains a light socket for a 15-watt candelabra-type lamp. The lens and light are supported on an arm which is secured to the post by means of a C-type clamp. The arm has universal joints, which permit you to set the glass at any position for both sawing and filing. A special plug connector on the extension cord connects with the outlet cap located on the front of the machine above the table light outlet. This outlet is fused for 1 ampere; you should not use it for any other light extension where more than 15 watts will be consumed. You use the magnifying attachment when precision sawing and filing to close tolerances are required.

Disc-Cutting Attachment. You can use the disc-cutting attachment to saw internal or external circles and discs. The diameter of the circle which you can cut is limited to the length of the cylindrical bar on the attachment or to the throat depth of the machine. The disc-cutting attachment consists of three parts: (1) a clamp and cylindrical bar, which can be fastened to the saw guidepost; (2) an adjustable arm that slides on the cylindrical bar; and (3) a picot or centering pin – all shown in figure 3-20. The disc must be laid out and the center drilled with a center drill to a depth of 1/8 inch to 3/16 inch to provide a pivot point for the centering pin. You can feed the work into the saw band by hand or by power feed. NOTE: If you use power feed, you should lock the right cable so that all the force of the weight will be applied to the left cable. Wrap the chain on the left cable around the work two turns. When the weight is applied, the work will rotate clockwise into the saw. The centerline of the centering pin must be in line with the front edge of the sawteeth and at the desired distance from the saw band.

Exercises (236):

1. Describe how and why the magnifying attachment is used with the contour machine.

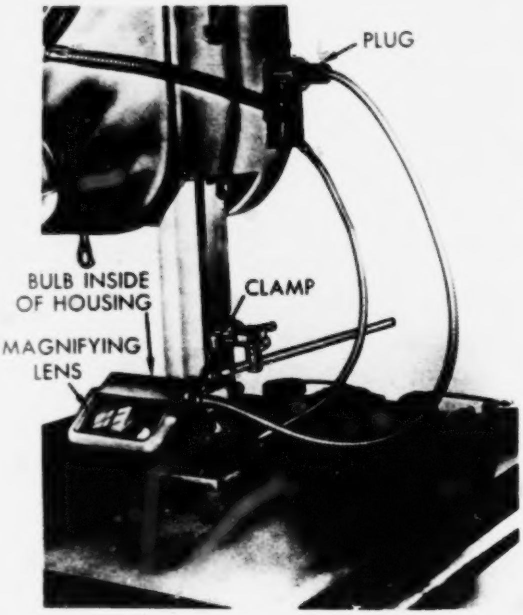


Figure 3-19. Magnifying attachment.

2. What are the three parts of the disc-cutting attachment and how are they used?

237. State the purpose and operation of the angular saw guides, the rip fence, and both types of mitering attachments.

Angular Saw Guides. Angular saw guides twist the saw band to a 30° angle and allow work that would normally be too long to saw to be machined; for example, the bar shown in figure 3-21. The tension must be less than normal to permit the saw band to

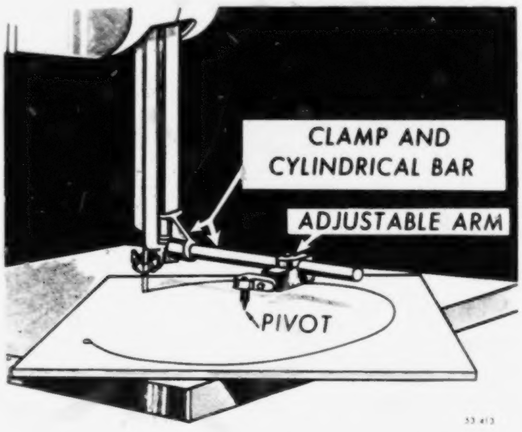


Figure 3-20. Disc-cutting attachments.

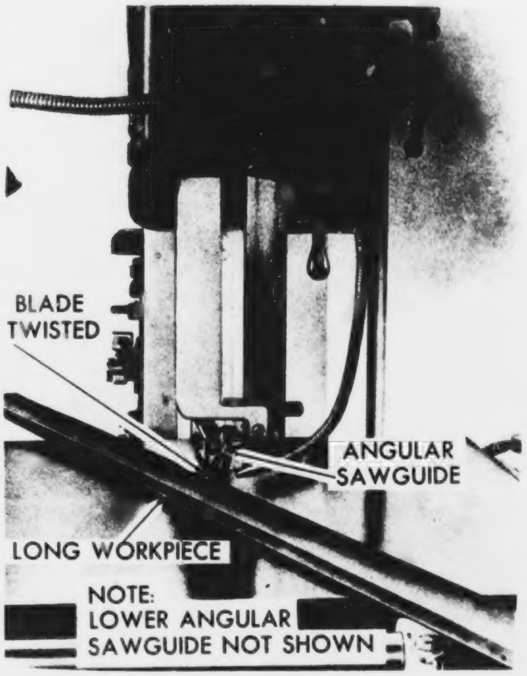


Figure 3-21. Angular saw guides.

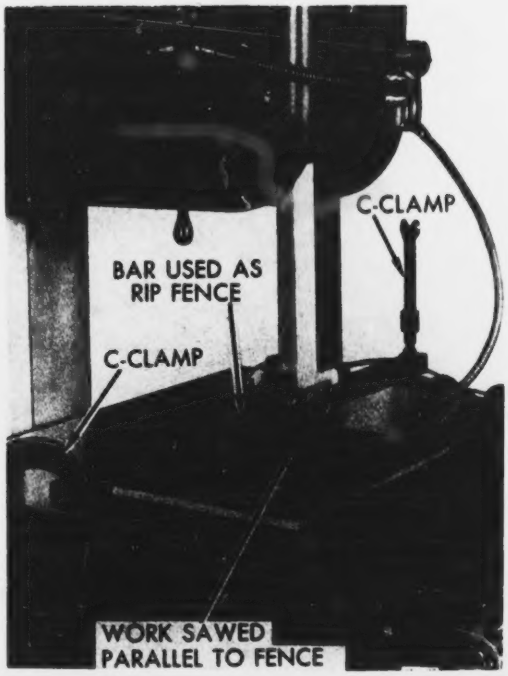


Figure 3-22. Improvised rip fence.

twist without causing the inserts to wear excessively.

Rip Fence. You use the rip fence to cut stock so that opposite sides are parallel. The fence must be set parallel to the table slot and located the desired distance from the saw band. A rip fence can be improvised by clamping a metal bar to the table, as shown in figure 3-22. Accurate results can only be obtained if the saw is properly set up and a sharp saw band is used.

Cutoff and Mitering Attachment. You use the cutoff and mitering attachment, shown in figure 3-23, for cutting off, mitering, and ripping operations. Clamp or hold the stock to be sawed in position against the attachment. You can set the attachment at an angle with a protractor, using the table slot as a reference line. A gage rod can be extended from the attachment and used as a stop when identical lengths are sawed. The attachment is swung on the slide rod and allowed to hang below the tabletop when it is not in use. NOTE: When you use the contour machine for cutting off round stock, *do not* try to hold the work by hand only. The cutting action can cause the stock to rotate and either cause injury to you or damage to the stock or both. A small vise clamped on the stock upside down and resting on saw table will prevent the stock rotating and still allow the stock to lie flat on the table.

All-Purpose Mitering Attachment. You can perform three operations with the all-purpose mitering attachment, shown in figure 3-24. You can use it with hand or power feed for (1) ripping, (2) cutting off, or (3) mitering. You can notch, square, rip, or miter rods, tubes, bars, channels, rails, and irregular shapes with accuracy. The attachment is mounted on the sawing side of the table and is fastened to a guide rail on the front edge of the table. The attachment has a graduate plate with an adjustable work stop on the mitering bar and a lockscrew on the miter head, which enables you to set the attachment at any desired angle.

Exercises (237):

1. What is the purpose of the angular saw guides and how do they work?

2. What is the purpose of the rip fence and on what does accurate results depend when it is used?

3. State the purpose of the two mitering attachments and explain the main difference between them.

238. Explain contour machine installation, lubrication, troubleshooting, and maintenance techniques.

Installation and Lubrication. The contour machine should be installed so that the light strikes the table from over the right shoulder of the operator

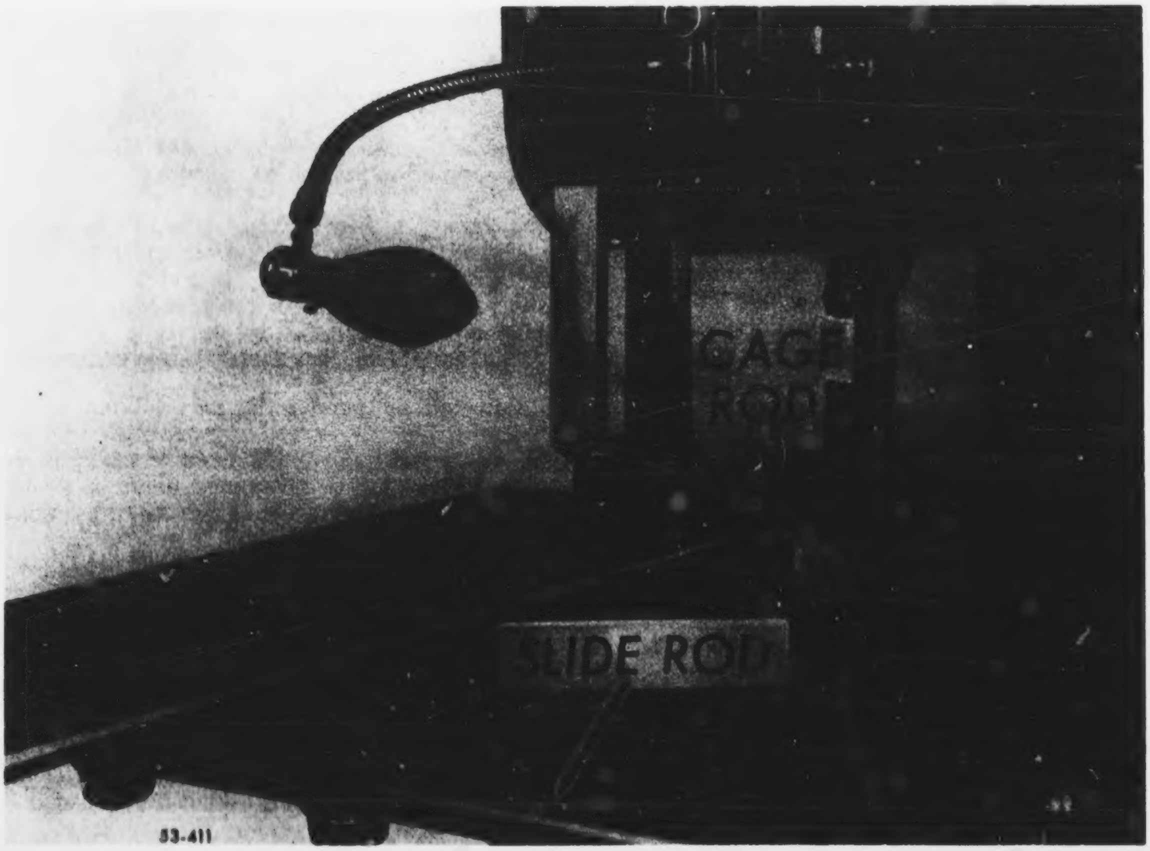


Figure 3-23. Cutoff and mitering attachment.

when he is in position for sawing and from over his left shoulder when he is in position for filing or polishing. The machine should be rigid and level on a solid floor to insure that the frame will not spring out of alignment. After the machine is in place, shim under the base until the post and the keeper block align with each other and are in a vertical plane. You can align the post and keeper block with the aid of the square head and blade, a combination square. When alignment is obtained, bolt the machine securely to the floor with lag screws through the holes in the flanged base of the machine.

Lubrication. When you are lubricating the contour machine you should use a lubrication chart to insure that all parts will be lubricated as recommended by the manufacturer. The lubrication chart usually includes the following items:

- Transmission. The transmission should be oiled monthly. Use a good grade of transmission oil and fill the case until the oil appears in the filler pipe elbow.
- Variable speed pulley. The variable speed pulley should be oiled about once a month with a good grade of spindle oil. This unit should not be overoiled, because excess oil causes the belt to slip.
- Drive motor. The drive motor has wool-packed sleeve bearings and should be oiled about once a month with a good grade of machine oil.
- Grinder motor. The grinder motor can be oiled through the two spring cap oil fillers on the butt welder panel. A few drops of machine oil about once a month are sufficient.
- Moving parts. Moving parts, such as the slide rod, slide screw, thrust bearing of the upper wheel, power feed screw, and speed change screw, should be oiled occasionally to assure free movement.
- The air pump has plastic vanes and should not be lubricated with oil. If it becomes necessary to lubricate the air pump, pour powdered graphite into the air intake while the pump is operating.

Troubleshooting and Maintenance. Since the contour machine is a simple machine with few moving parts, only a few problems normally occur and not many adjustments are required. We will discuss some of the most common problems and the steps to take to correct them.

V-belt slippage. V-belts tend to stretch after continued operation. You can adjust for this condition by increasing the counterbalance. This is

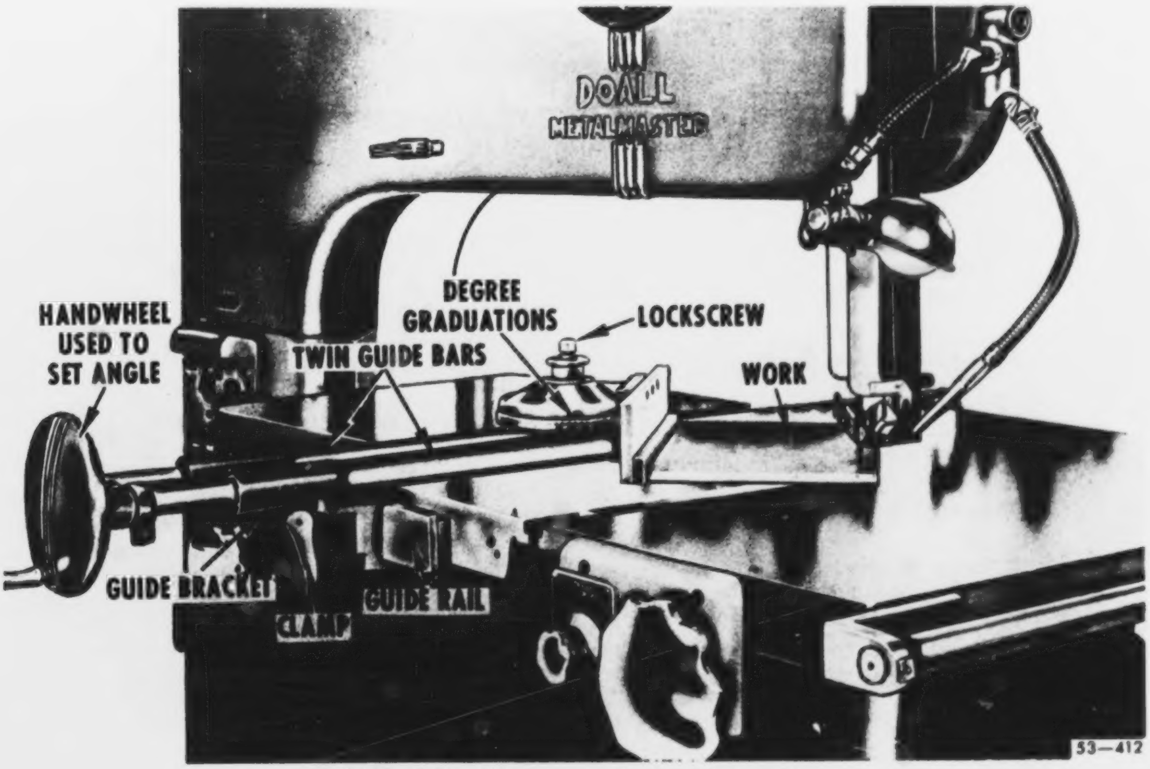


Figure 3-24. All-purpose mitering attachment.

done by loosening the nut on the base. equalizer spring. This results in placing more of the dead weight of the motor on the drive belt. However, too much weight causes unnecessary wear on the bearings and shaft. Proper counterbalance is attained when the motor mounting base just touches the base of the machine when the motor is allowed to drop from a height of 1 inch.

Butt welder failure. Only certain adjustments can be made on the butt welder. The movement of the welder jaws cannot be changed. The switch cutoff can be adjusted in or out to regulate the timing of the weld. A clockwise rotation of the cutoff switch adjustment screw usually causes a slower breaking of the welding circuit to give more heat at the point of weld, while a counterclockwise adjustment gives less heat. If the failure is electrical, you should not attempt the repair yourself but should have the repairs made by an electrician.

Incorrect tracking. Incorrect tracking of the saw band results in excessive pressure on the guide block thrust rollers, causing the saw to wear out the bearing cap. When this occurs, remove the worn cap from the bearing and press on a new one.

Air pump stoppage. Sticking plastic vanes in the pump are caused by dirt and oil and will result in air pump failure. Clean the vanes with a dry brush or rag and lubricate them sparingly with powdered graphite.

Worn guide inserts. Worn or scored inserts on the surface that make contact with the saw band should be reground to a 45° angle. After grinding the inserts, remove the sharp edges with an oilstone.

Grooved tires. Saw band slippage causes wear and grooves on the tire of the lower wheel; excessive tension on a small, narrow saw band causes wear and grooves on both the lower and upper wheels. If the wear causes the saw band to ride in the grooves, it is impossible to track the saw band properly. Remove the tires, turn them inside out, and replace them on the wheels. If the wear is excessive and the grooves are deep, install new tires.

Exercises (238):

1. If after a contour machine has been installed, you find that the frame is sprung out of alignment, explain how to realign it.

2. Explain the technique for lubricating the grinding motor. With what frequency should it be accomplished?

3. With what should the air pump be lubricated? Why?

4. Explain the techniques for correcting the problem of worn and grooved tires on the upper and lower band wheels.

CHAPTER 4

Drill Press Work

THE DRILL PRESS is used primarily to cut round holes through some type of material. It employs a variety of cutting tools, of which the twist drill is the most common. Drilled holes may be finished by reaming, counterboring, countersinking, and spot facing. In this chapter we will discuss drill presses and the maintenance of cutting tools, tool and work setups, speeds and feeds, and common drill press operations.

4-1. Maintenance of Cutting Tools

The success that you have using the drill press will depend to a large degree on your ability to select, use, and maintain the various cutting tools used with drill press machines. In this section we will review the common types of drill presses, and then discuss the types and uses of the various cutting tools used with them. We will also discuss drill bit sharpening techniques.

239. Describe common types of drill presses, and list uses peculiar to each.

Types of Drill Presses. There are many types of drill presses, but we will discuss only the three general-purpose types most commonly used in the AF. They are the sensitive, the plain, and the heavy duty.

Sensitive. Sensitive drill presses are designed to drill very small diameter holes at very high speeds. They do not have power feeds. The operator feeds the drill into the work by hand and can "feel" the cutting action taking place. These drills may be bench or floor mounted, although the bench type is probably the more commonly used. The size of a sensitive drill is designated as the maximum diameter of work it is capable of drilling. For example, a 10-inch drill press would be capable of drilling a hole in the center of a piece of work 10 inches in diameter.

Plain. Plain drill presses are used for light- and medium-type work. The floor-mounted type, shown in figure 4-1, is found in many Air Force machine shops. The bench type, such as the one shown in figure 4-2, is also quite common. Some of these types are designed so that the drill may be fed by power. The sizes of plain drill presses are designated in the same manner as for sensitive types.

Radial. Radial drill presses, such as the one shown in figure 4-3, have the head mounted on an arm instead of directly on the column of the machine. You can raise, lower, and swing the arm to the right and to the left, and move the head along it. This allows you to position the spindle over the work—a great advantage when you are working with heavy, bulky items. Power feeds and reversible spindles, usually provided, increases the capability of the machine. Radial drill presses are good all-around machines. They are suitable for both light- and heavy-duty work, and are capable of doing highly accurate work. The size of a radial drill press is designated by the length of the arm. This is the distance from the center of the spindle to the edge of the column when the head is located as far out as possible on the arm. For example, a radial drill press designated as having a 3-foot arm will drill to the center of a 6-foot circle, and the length of the arm will actually be greater than 3 feet.

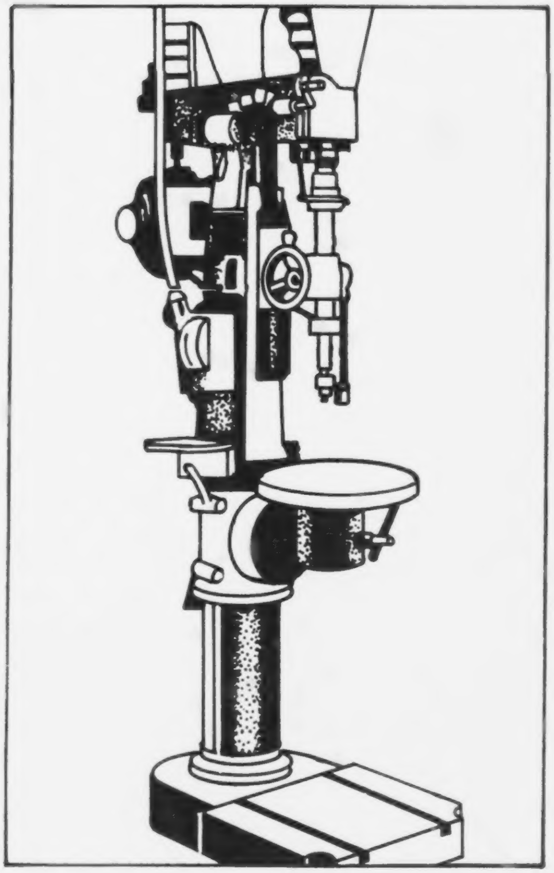
In order to understand the operation of a radial drill press and its advantages, you should be able to recognize the basic parts of the machine. There are four basic parts: (1) base, (2) column, (3) arm, and (4) head, as shown in figure 4-3. All of the features of the radial drill press are included in these four parts.

The base of the radial drill press is the large cast section located at the bottom of the machine (figure 4-3,M). The base has several functions. It is a foundation on which the rest of the machine is mounted. It provides a place to mount the worktable. The base also has a reservoir for cutting lubricants and coolants.

The column is the upright portion of the radial drill press (figure 4-3,C). The column is a large precision-ground shaft which supports the arm, column clamp lever, and the arm locking lever.

The arm (figure 4-3,D) of the radial drill press has many functions and advantages. It can be moved around the column 360°. This is a great advantage in locating the drill over large work. The arm gives support to the spindle drive motor and to the head of the machine. It provides the ways along which the head is moved.

The head (figure 4-3,A) houses many parts of the radial drill press. It houses the speed change gearbox, feed change gears, and the spindle.



53-85

Figure 4-1. Floor-mounted drill press.

Exercises (239):

1. Give a brief description of a sensitive drill press and state its purpose.

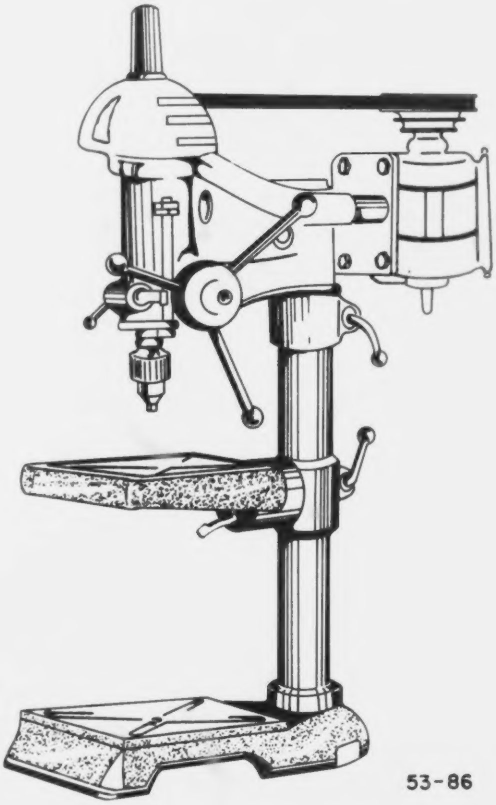
2. What advantages does the radial drill press have over the plain drill press?

3. On which of the four main parts (base, column, arm, head) of the radial drill press are the following items located?
   a. Coolant reservoir __________
   b. Spindle __________
   c. Arm __________
   d. Worktable __________
   e. Speed change levers __________
   f. Spindle drive motor __________
   g. Feed change gears __________
   h. Head __________

240. Describe the various types and various uses of cutting tools used in drill press work.

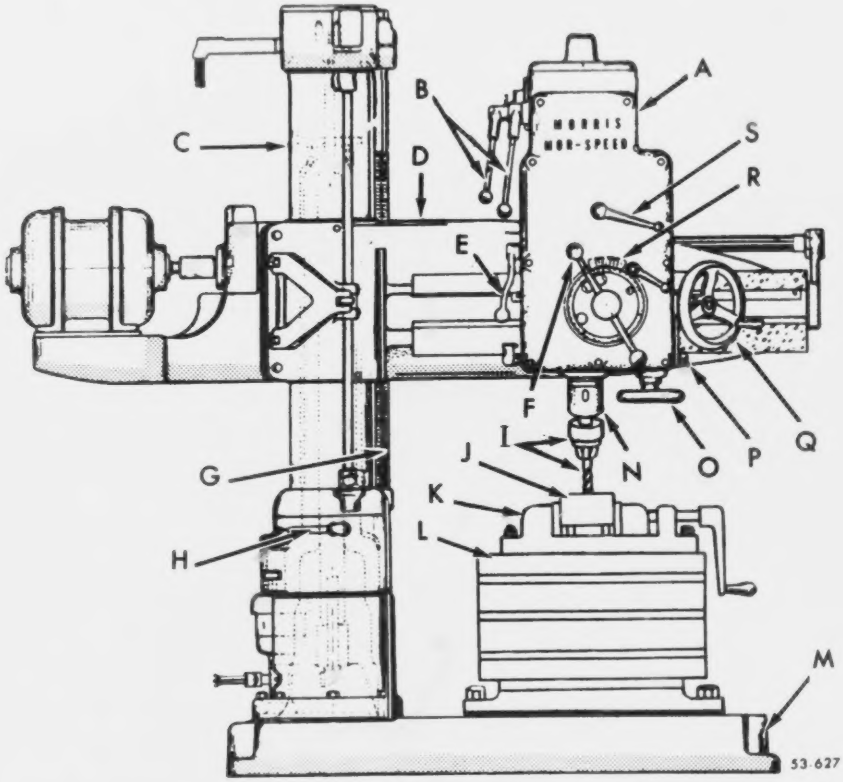
Cutting Tools. Drill presses are used to do more than just drill holes, although that is their primary function. The different operations are accomplished by changing the type of cutting tool used. So let's examine some of the more common cutting tools.

Drill bits. The drill bit is the primary cutting tool in most drill press operations. Its main purpose, of course, is to cut round holes in the stock or material. There are three main parts to a



53-86

Figure 4-2. Bench-mounted drill press.



A. Head
B. Speed change levers
C. Column
D. Arm
E. Head clamp lever
F. Feed clutch lever
G. Elevating screw and lever
H. Arm clamp lever
I. Chuck and drill
J. Work
K. Vise
L. Table
M. Base
N. Spindle
O. Feed hand wheel
P. Start, stop, and reverse lever
Q. Head traverse hand wheel
R. Feed dial
S. Feed change lever

Figure 4-3. Radial drill press.

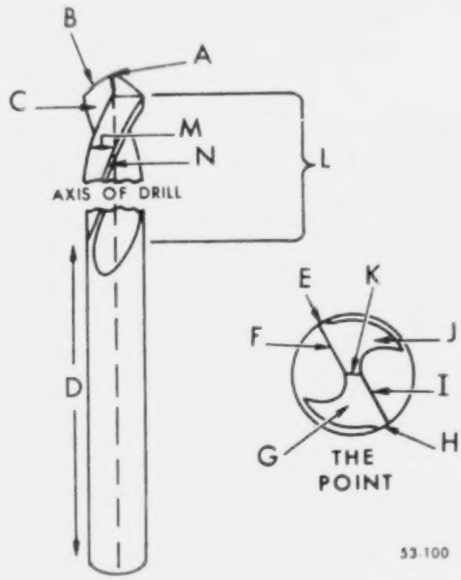
drill; shank, body, and the point, as shown in figure 4-4.

The shank (L) is that part of a drill behind the flutes which is used to hold the drill in a chuck, collet, or spindle. Several types of shanks are available. The most common types are the straight and taper shanks. Most drills larger than ½ inch in diameter are made with Morse taper shanks. The tang, which is common the taper shank drills, is that flattened portion on the shank end of the drill that assists in driving the drill.

The body of a drill (L) is that portion of a drill between the point and the shank. There are several parts that make up the body of a drill, such as flutes, web, and margin. Each of these parts performs some important function, but the drill must be sharp for the parts to complete their tasks.

The point, as shown in figure 4-4, is the cone-shaped portion on the cutting end of the drill. It is this portion which is ground to form the cutting edges. The dead center (K) or chisel edge is the portion connecting the bottom of the flutes (C) at the extreme end of the drill. It is formed by the intersection of the cone-shaped surfaces of the point. It should always be in the exact center of the axis of the drill. The cutting lips (F) are the actual cutting edges of the drill. They extend from the chisel edge to the periphery of the drill.

Drill bits are produced in a variety of shapes and sizes, but they are generally grouped into two classes; straight shank and taper shank. Straight shank drill bits include many sizes and lengths. The diameters are designated by numerical codes, by alpha codes, or by their actual diameter. For example, number drills include sizes from number 97 (0.0059 dia) to number 1 (0.228 dia); letter (alpha) drills sizes from A (0.234 dia) to Z (0.413 dia); and fractional drills include sizes from 1/16 inch diameter to 2 inches diameter. (Straight shank drill bits over 5/8 inch diameter are not commonly used in the Air Force.) Metric drill bits are also produced in straight shank form in sizes from 0.20 millimeter



A. Dead center
B. Lip of cutting edge
C. Flute
D. Shank
E. Margin
F. Cutting lip
G. Lip clearance
H. Margin
I. Cutting lip
J. Lip clearance
K. Dead center
L. Body
M. Body clearance
N. Margin

Figure 4-4. Twist drill.

diameter to 16.0 millimeters diameter. (Extra long metric straight shank bits include sizes to 25.0 millimeters diameter.)

Taper shank drill bits are preferred for drilling medium to large holes because the tang on the shank prevents the bit from spinning in the spindle socket. These drill bits are held in the spindle by friction between the drill taper and the spindle socket. They provide a more positive mounting than do straight shank bits, which can the drill chuck when subjected to heavy cutting pressure. Also, drill chucks with drill bit capacities much larger than ¾ inch diameter are uncommon in the Air Force. Taper shank bits are produced in sizes from ⅛ inch diameter to 2 inches diameter (larger sizes are produced, but are uncommon). Metric bits can also be obtained with tapered shanks.

Reamers. A reamer is a fluted cylindrical tool which is used to size drilled holes to precise diameters. They are also used to produce holes that are round, smooth, and straight. The teeth are unequally spaced around the body of the reamer to prevent chatter. Reamers with spirally cut teeth are more desirable than those with straight-cut teeth because they produce a slightly smoother and more accurate hole. This is because of the extra shearing action that the spiral flutes lend to the teeth. The two most common types of reamers are the rose reamer and the standard fluted chucking reamer, as shown in figure 4-5. The rose reamer is mainly a roughing reamer and cuts only with the 45° bevel on the end of the teeth. It has a slight back taper along its length from the cutting end to reduce friction. The amount of metal that may be removed with a rose reamer ranges from 0.005 to 0.015 inch and sometimes to as much as 0.030 inch for roughing purposes.

The fluted chucking reamer, on the other hand, has clearance or relief along the entire length of its side-cutting edges or lands. It is used for finishing holes that are smooth and true to size. Since fluted chucking reamers have a greater number of teeth and thinner lands than rose reamers, as you can see in figure 4-5, they are intended for removing only small amounts of metal in order to accurately size and finish a hole. The amount of metal removed by this type of reamer usually varies from 0.003 to 0.005 inch, with 0.010 inch as a maximum.

Countersinks and center drills. A countersink (which is also referred to as center reamer) is used to enlarge the end of a drilled hole with a large enough chamfer to enable a countersunk (shallow cone shape) bolt or screwhead to lie flush with, or just below, the surface of the work. It can also be used to chamfer a hole prior to tapping threads.

The countersink has teeth milled on its cone-shaped end at standard included angles of 60°, 82°, 90°, or 100°. If you don't have the correct size countersink, you can grind a drill to the required angle to serve as a substitute.

The center drill is really a combination drill and countersink which is used to provide a guide for

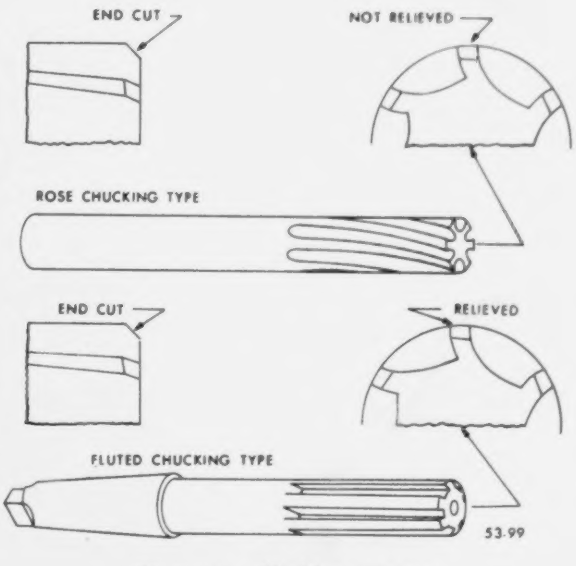


Figure 4-5. Machine reamers.

the drill bit. Center drills are produced in a variety of sizes from ⅛ inch (the body diameter) to ½ inch diameter. The center drill you choose should at least be larger in diameter than the length of the web of the first drill bit that you intend to use.

Counterbores. Counterbores are used to make cylindrical-shaped enlargement at the surface end of a drilled hole usually for the purpose of recessing the head of a screw or bolt. A counterbored hole has a flat bottom. Spot facing (providing a smooth flat surface that is square with the hole) is also accomplished with a counterbore.

The counterbore is an end-cutting tool with three or more straight or spiral teeth relieved at the end to form cutting edges. A pilot in the end of the counterbore centers it in the hole and guides the cutting action. The pilot can be a part of the tool or can be the replaceable type. The body diameter of the counterbore is usually 0.003 to 0.005 inch larger than the standard size; for example, a counterbore for a ½-inch hole may be from 0.503 to 0.505 inch diameter. The pilot is usually from 0.001 to 0.002 inch undersize to prevent it from binding in the hole or enlarging it.

Try a few questions now, and then we will review the drill sharpening procedures you learned in your 3-skill-level studies.

Exercises (240):

1. Name and briefly describe the three main parts of a drill bit.

2. Why are tapered shanks drills recommended for use when drilling larger diameter holes?

3. Describe the main difference in design between the rose reamer and the standard fluted reamer.

4. What are the standard included angles that can be obtained on countersinks?

5. State the uses of a counterboring tool.

241. Explain the procedures for preparing the pedestal grinder and the grinding wheel for sharpening drill bits.

Grinder Preparation. Most of the drill sharpening that you will do in the Air Force will be done on a pedestal grinder. The grinder must be properly prepared if you are to do an efficient job of sharpening a drill bit. A fairly close grained grinding wheel of medium hardness is the best choice for general offhand drill sharpening.

Before grinding a drill, you should dress the abrasive wheel, and, if necessary, true it. The terms "dressing" and "truing" are frequently confused. Dressing is the reconditioning of the abrasive surface of a wheel that has lost some of its cutting ability. This is caused by glazing or loading up (filling the spaces between abrasive particles) or dulling the abrasive particles. Truing is restoring the abrasive wheel to its correct geometrical shape in relation to its axis. Truing is not required as frequently as dressing. The Huntington type dresser, which consists essentially of a number of circular metal cutters mounted on a spindle in a holder, is the most commonly used type of offhand dressing tool. Figure 4-6 shows this tool in use. Here the dulled abrasive grains and any loading of metal or foreign material are being removed so that sharp grains are being presented to the work. Before using the wheel dresser, position the tool rest so that the legs of the dresser may be hooked over it, as shown in figure 4-6. CAUTION: Be sure that the grinder has been turned off before you attempt to loosen the tool rest. After positioning the tool rest, turn the grinder on, and bring the dresser into contact with the wheel. Never stand in front of a grinding wheel until after it has been running for several minutes. It may possibly disintegrate when it is first turned on. Also, never operate a grinder without wearing approved goggles or a face shield.

Pass the wheel dresser back and forth across the face of the abrasive wheel until it has been properly dressed and trued. Too little pressure will cause excessive sparking and rapid wearing of the dresser cutters and should be avoided. After completing the dressing, turn the grinder off and position the tool rest not more than ⅛ inch away from the wheel surface.

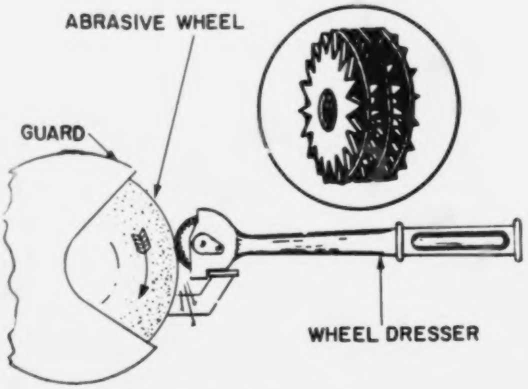


Figure 4-6. Huntington wheel dresser.

Exercises (241):

1. What is the best general-purpose grinding wheel to mount in the pedestal grinder for offhand drill sharpening?

2. What are the two operations that might be required prior to preparing a grinding wheel for sharpening drill bits? Explain the purpose of each.

3. Explain the positioning of the tool rest during the wheel dressing and truing operations; after the dressing and truing operations.

242. State the proper drill point angles for drilling various materials.

Determining Drill Angles. Drills with a lip clearance angle of 12° to 15°, figure 4-7, part 1, and an included angle of 118° (59° + 59° = 118°), figure 4-7, part 4, are used for most general drilling operations on carbon and soft alloy steel. Harder materials require less clearance than do the softer ones. Too much clearance for the hardness of the material causes a rapid breakdown of the cutting edge, as shown in figure 4-7, part 3. Sharper included angles give faster, smoother production with soft materials. Flatter points have longer wear on drills used on hard, tough steels. Drills have a tendency to "hog-in" (grab) when drilling brass. Grinding the face of the cutting edge parallel to the drill axis, as shown in the illustration for brass and soft bronze in figure 4-8, helps reduce this problem. Drills used to drill any kind of thin metal should also be ground this way. As the drill is shortened by repeated sharpening, the web grows thicker. Maximum ease of penetration and wear resistance can be obtained by thinning the web to its original thickness. A "notched point," as shown in figure 4-8, is helpful when you drill deep holes. Figure 4-8 shows the recommended angles for various materials.

After a few more questions, we will put what we have learned to use as we discuss the actual procedures for sharpening a drill bit.

Exercises (242):

1. What is the best clearance angle and included angle for general nonhardened steels?

2. State the general rule of thumb for the included angle on softer materials; or harder materials.

3. How can you prevent the drill bit from grabbing when drilling brass?

243. Explain the procedures for grinding and checking the angles of a drill bit.

Grinding Drill Point Angles. The actual grinding operation is relatively simple. Position the drill for the desired cutting edge angle. Using your fingers below the drill as a pivot, push the shank down, as shown in figures 4-9 and 4-10. This grinds the cutting edge angle and the clearance angle at the same time. You need not rotate the drill except for very large sizes. First grind one cutting edge, then the other, as many times as necessary, until the grinding is completed. Make frequent checks to insure that the proper angles and lengths of cutting edges are being maintained. NOTE: Never raise the shank of the drill higher than the cutting edge while you are grinding, or a negative angle will be produced.

When drills are manufactured they are made so that the web of the drill is thicker at the shank end than at the point. This is done to provide strength. As the drill wears and is ground several times it may become necessary to thin the web. Thinning the web is done to achieve maximum cutting efficiency, or ease of penetration and minimum wear. The web should be thinned to approximately its original thickness. This is usually done with a round-faced abrasive wheel, as shown in figure 4-11.

Another method of thinning the web of a drill, known as notching, is used to improve the performance of a drill used in hand feed operations, such as in crankshaft drilling. This type of thinning works well when the drill is to be used in a hand drill. Notching is similar to thinning, as shown in the right half of figure 4-11, except that the sharp-cornered hand abrasive wheel is used instead of a round-faced wheel.

Checking Drill Point Angles. To sharpen a drill accurately, you must know how to check angles. You can check the cutting edge angle with a drill grinding gage, as shown in figure 4-12, or with the protractor head and blade, as shown in figure 4-13. You can also check the length of the cutting edge with these same tools. Both lips must be of equal length, or oversize holes will be produced, as shown in part 5 of figure 4-7, or the drill may break. Check the clearance angle by using a clearance gage made of paper. Use a strip of paper 3 inches wide and 8½ inches long. Place a mark on the margin 1¾ inches from the lower side and bring the upper right-hand corner into contact with it, as in figure 4-7, part 2. Insert the drill in the gage and compare the clearance angle to the angle of the paper strip. The 1¾-inch dimension will produce an angle of approximately 15° while a 2-inch dimension will produce an approximate angle of 12°.

Exercises (243):

1. Explain the procedure for grinding the clearance angle on a drill bit.

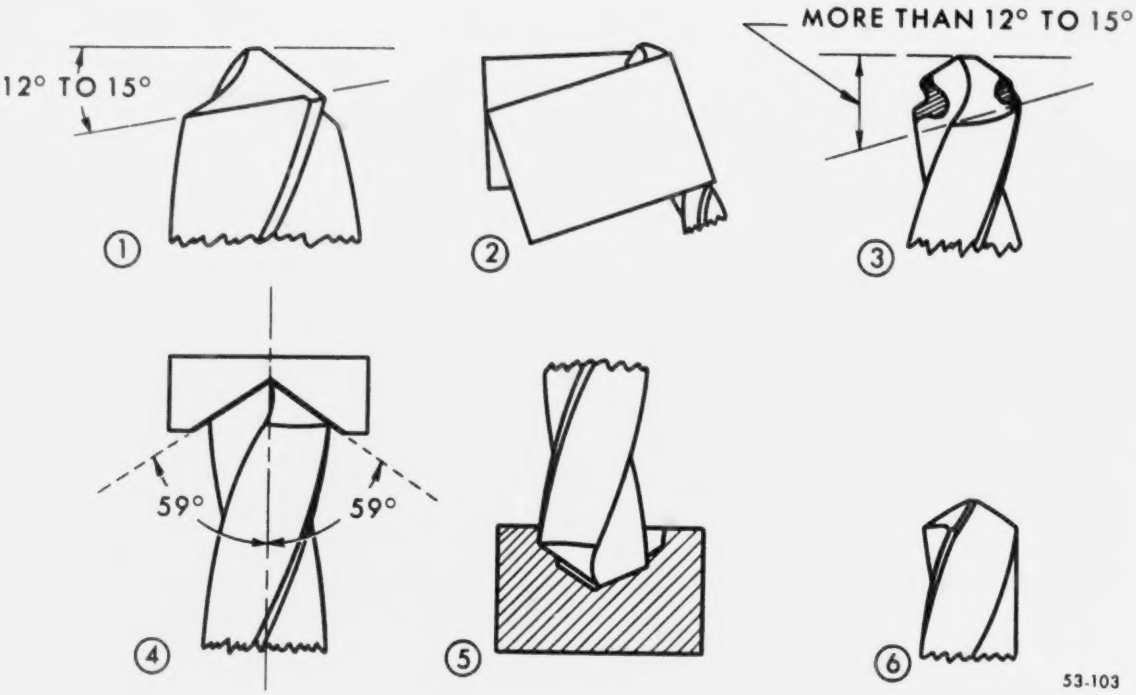

12° TO 15°
MORE THAN 12° TO 15°
①
②
③
59°
59°
④
⑤
⑥
53-103

Figure 4-7. Drill grinding hints.

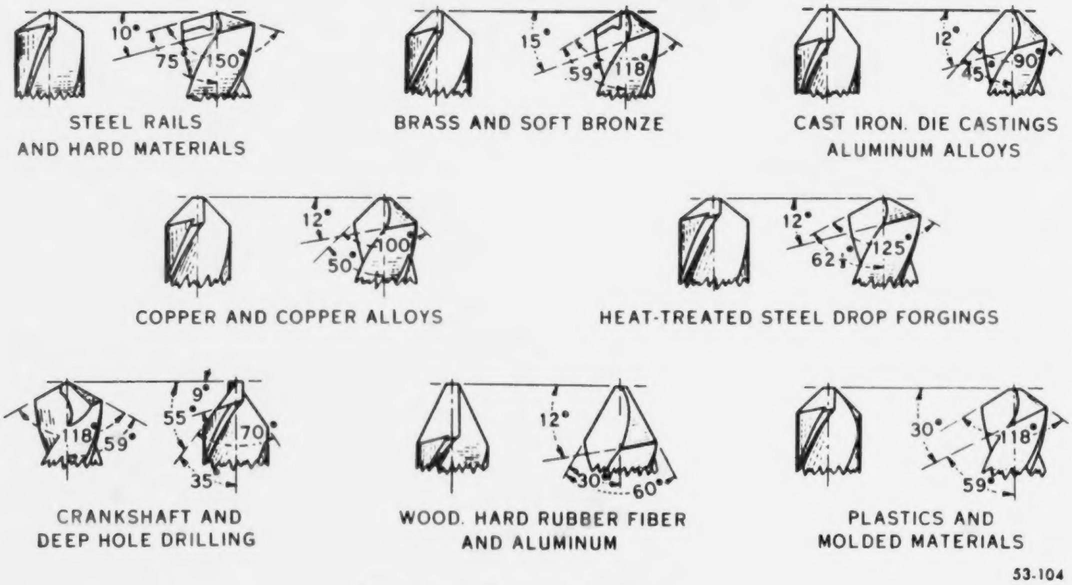

10°
75°
150°
STEEL RAILS AND HARD MATERIALS
15°
59°
118°
BRASS AND SOFT BRONZE
12°
45°
90°
CAST IRON. DIE CASTINGS ALUMINUM ALLOYS
12°
50°
100°
COPPER AND COPPER ALLOYS
12°
62°
125°
HEAT-TREATED STEEL DROP FORGINGS
118°
59°
9°
55°
70°
35°
CRANKSHAFT AND DEEP HOLE DRILLING
12°
30°
60°
WOOD. HARD RUBBER FIBER AND ALUMINUM
30°
118°
59°
PLASTICS AND MOLDED MATERIALS
53-104

Figure 4-8. Shapes of drill points.

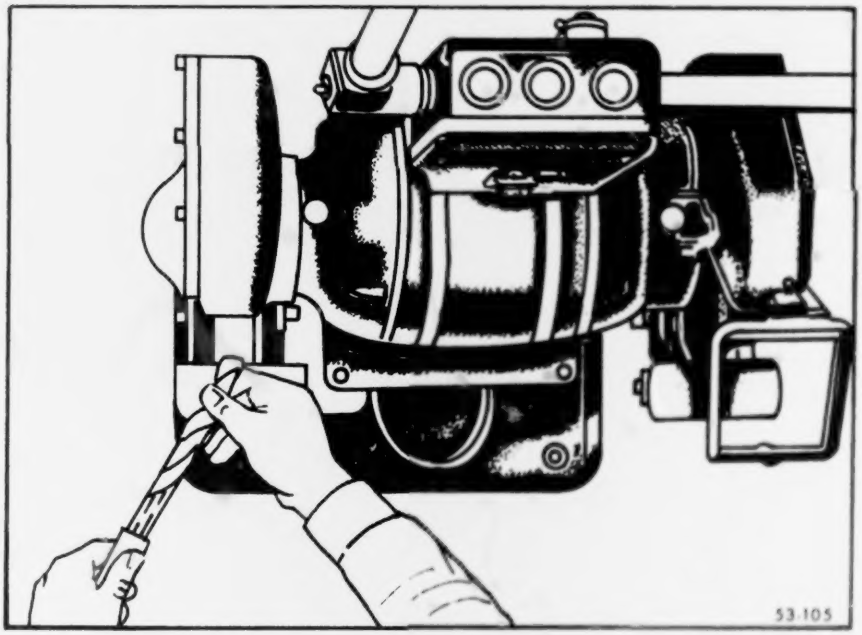


Figure 4-9. Positioning a drill for grinding

2. Explain two methods of web thinning.

3. Explain the procedure for checking the clearance angle.

4. State the tools that can be used to check the included angles of a drill bit.

4-2. Tool and Work Setups

Satisfactory results cannot be expected from a drill press operation unless the tools and work setup has been properly accomplished. We will discuss both tool and work holding devices and setups in this section. Our discussion of work setups will pertain mainly to the radial drill press.

244. State the purpose and explain the use of various tool holding devices for drill press work.

Tool Holding Devices. The spindle of a drill press has a tapered hole in the end which is used to hold a cutting tool or a drill chuck. This hole is usually reamed to one of the standard Morse tapers, and you can insert a tool having a tapered shank with the same Morse taper directly into the spindle hole. When you use a taper, it automatically aligns the tool with the hole, and friction or the wedging action of the taper holds the tool in place. To prevent taper shanked tools from slipping, a tang on the end of the shank, such as those shown in figure 4-14, fits into a slot in the spindle. When the tool shank is smaller than the spindle hole, socket reducers, shown in figure 4-14, which are also called drill sleeves, can be used to provide the proper fit. You may need more than one reducer, however, to fit very small shanks to larger holes.

There are also step reducers which allow large shanked drill bits to be used in spindles with smaller tapers. On the step reducer the drill bit fits into a large tapered socket on one end and a smaller tapered shank on the other, and that fits into the spindle. Be careful with this type of setup, however,

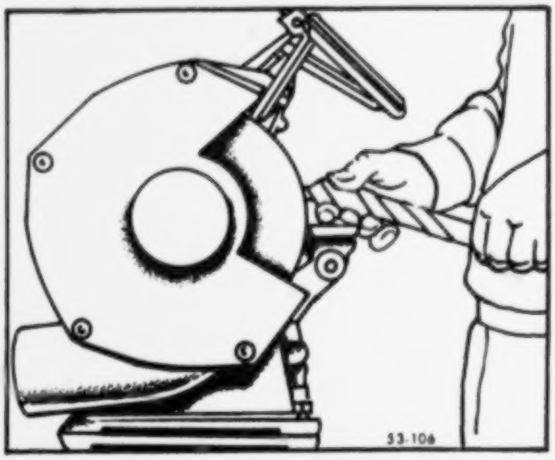


Figure 4-10. Grinding a drill.

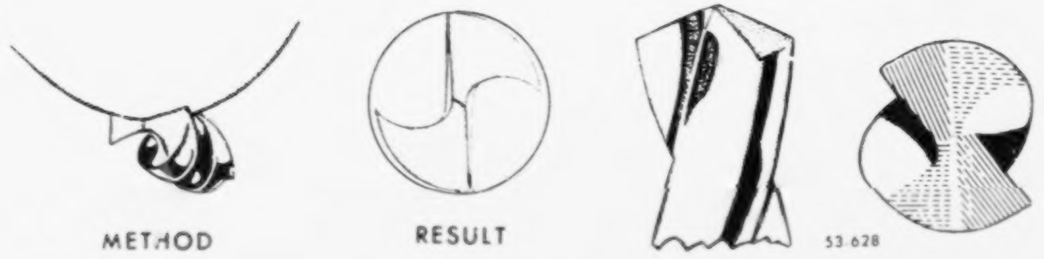


Figure 4-11. Methods of thinning the web.

because the drill bit diameter is probably beyond the recommended capacity of the drill press and must be used carefully with reference to feed. Also, this type of setup is usually quite heavy and, therefore, the probability is increased that it will lose from the spindle during the operation.

Tools having straight shanks are held by a drill chuck, shown in figure 4-14. Drill chucks have three self-centering, movable jaws that grip the tool shank. You tighten and release the jaws by means of a drill chuck key. CAUTION: Never leave the chuck key in the chuck. The shank of a drill chuck can usually be inserted directly in the tapered spindle; however, a socket reducer may be required in instances where the shank of chuck is of a smaller size taper than the one in the spindle.

Before you insert a drill chuck shank, a drill bit shank, or a reducer into a drill press spindle, be sure to check for burrs or dirt particles on either of the mating surfaces. Even a very small burr could cause runout of the cutting tool or damage to the spindle.

Exercises (244):

1. State the purpose of the tapered socket in the drill press spindle.

2. How does the spindle prevent a tapered drill bit from spinning in the spindle socket?

3. When you use the drill chuck, what must you do prior to inserting the chuck into the spindle?

245. Analyze the use of various work holding devices used to make work setups on the radial drill press.

Work Holding Devices Used on Radial Drill Presses. Successful drill press work depends to a great extent upon the manner in which work is held. Properly mounted work requires various holding devices, such as the drill press vise, V-blocks, clamps, and straps. The practice of holding work by hand on the drill press is dangerous and can easily result in damaged work, broken drills, and injury to the operator.

Vise. The vise is the most commonly used holding device for drill press work. It usually has slots to receive T-slot bolts and can easily be secured to the machine table. The work is normally supported on parallel bars to prevent drilling holes in the vise. Most vises are constructed with a movable jaw which is operated by a single screw. Vises are available in a variety of sizes and designs. A typical vise as used on the radial drill press is shown in figure 4-3.

V-blocks. V-blocks are easily adaptable for the support of cylindrical work. When you use V-blocks to support the work on a drill press table, you normally clamp the blocks directly to the table surface. Then clamp the work in the V-block. When work cannot be held in a vise or clamped to a V-block, you can clamp or strap it to the table surface. A strap can be easily made from a flat piece of steel with a hole drilled near the clamping end. The size and shape of these straps are governed by the nature of the work to be drilled. Clamps, on the other hand, usually have a specific shape, such as the flat, gooseneck, pin, and V-clamp.

Table. Because the radial drill press is capable of drilling large objects, the table is designed to allow

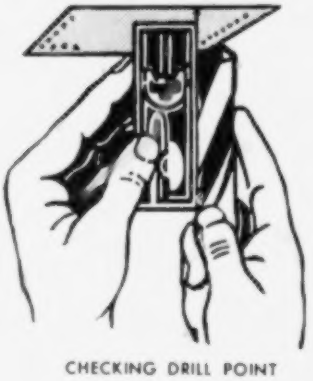


Figure 4-12. Drill grinding gage.

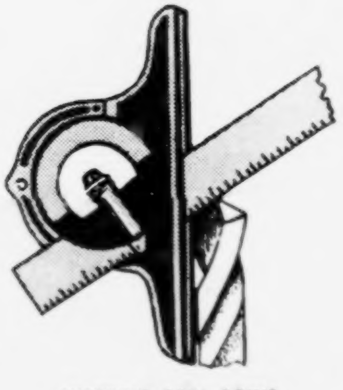


Figure 4-13. Protractor head and blade.

many variations in the way objects can be mounted and secured. Usually the table can be tilted 90° in one direction. There are normally two mounting surfaces; the top surface and an adjacent surface at 90° to the top surface. Each surface is provided with a series of T-slots to facilitate the use of tiedown bolts to secure the vise (as in figure 4-3), clamps, straps, V-bolts, or angle plates.

Before you mount anything on the table, you should check the graduated scale (usually located on both ends of table) to be sure that it is set at the required position. Also, check both the part to be mounted and the table mounting surface for burrs and dirt or grit particles. Burrs should be removed and the parts cleaned to be sure that the setup is true and that neither the part nor the table is damaged.

Exercises (245):

1. When using a vise to secure work in a drill press, what can you do to prevent the drill from cutting into the vise as it breaks through the work?

2. What work holding devices can be used when you cannot hold the work in a vise or V-block?

3. You must drill a series of holes, one of which must be at a 30° angle to the others, in a large work piece and you decide to clamp it to the table of a radial drill press. How can you set it up so that you can drill all the holes without repositioning the work on the table?

4-3. Calculate Speeds and Feeds

Correct feed and speed are necessary because incorrect feed and speed result in poorly drilled holes, wasted time and material, and damage to the cutting tools or equipment. However, no hard-and-fast rules can be given regarding the correct feed and speed to use. In this section we will examine feed and speed requirements, cutting foot speed conversions, and drill press speed changing techniques.

246. Analyze speed and feed requirements for drill press operations, and convert cutting foot speeds to revolutions per minute.

Feed and Speed. To obtain the proper feed and speed for a particular operation, you must take many factors into consideration, such as: (1) the hardness of the metal; (2) the depth of the hole; (3) the size, type, and condition of the cutting tool; (4) the operation being done; (5) the condition of the machine; (6) the work setup; and (7) the type of cutting lubricant being used. The actual feed and speed that you use will be your decision, after all the factors have been considered.

Feed. Feed is the distance the cutting tool advances into the work per spindle revolution. When you are using hand feed, you must apply enough pressure to maintain a cutting action without forcing the drill. You should drill the hole, and not "punch" it out. Applying too much pressure chips the cutting edges and may even split the drill along the web. When the drill begins to emerge, you should reduce the pressure to prevent the work from "climbing up" the drill; this is especially true when you are drilling very thin pieces. Figure 4-15 gives the recommended feeds when power feed is used.

Speed. The speed of a drill press refers to the number of revolutions per minute (RPM) of the spindle. It is necessary that you know how to

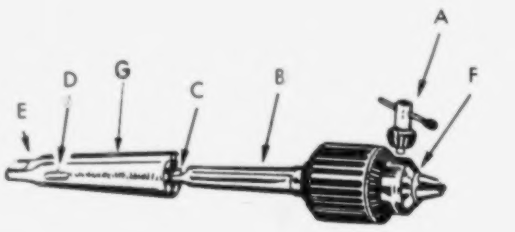


Figure 4-14. Socket reducer and drill chuck.

TABLE OF FEEDS	
DRILL SIZE (INCHES)	FEED (PER REV)
1/8 AND LESS	.001 TO .002
1/8 TO 1/4	.002 TO .004
1/4 TO 1/2	.004 TO .007
1/2 TO 1	.007 TO .015
1 AND LARGER	.015 TO .025

53—133

Figure 4-15. Drill feeds.

determine the speed to use for drilling and then how to set the machine to obtain the desired RPM.

As a drill rotates, a point located on its outer surface (periphery) travels a certain distance in 1 minute of time. The exact distance traveled depends upon the distance around the drill (circumference) and the speed of its rotation (RPM). When this distance is changed from inches to feet, it is called the surface foot speed (SFS). It has been determined through experience and experiment that various metals machine best when a specific SFS is maintained. This desired SFS is known as the cutting foot speed (CFS). Figure 4-16 gives the CFS for various materials. The lower CFS is generally used for drilling and rough machining operations. The higher CFS is ordinarily used for finishing operations.

Since a change of drill diameter results in a change of circumference, the RPM must be changed in order to obtain a desired CFS. For example, a drill ½ inch in diameter has a circumference one-half as great as a drill 1 inch in diameter and revolves twice as fast as the latter to obtain the same CFS. You can see that you must take the diameter of the drill into consideration when you are calculating the spindle RPM to use. The most practical formula for determining spindle speed is:

$$\text{RPM} = \frac{4 \times \text{CFS}}{\text{drill diameter}}$$

For example, if you were to drill a ½-inch hole in low carbon steel, the formula would be as follows:

MATERIAL	CUTTING FOOT SPEED
LOW CARBON STEEL	80 TO 110
MEDIUM CARBON STEEL	60 TO 80
HIGH-CARBON TOOL STEEL	50 TO 60
STEEL FORGINGS	50 TO 60
STAINLESS STEEL	30 TO 40
SOFT CAST IRON	100 TO 150
HARD DRILLED CAST IRON	70 TO 100
MALLEABLE IRON	80 TO 90
ORDINARY BRASS AND BRONZE	200 TO 300
HIGH-TENSILE BRONZE	70 TO 150
MONEL	40 TO 150
ALUMINUM AND ITS ALLOYS	200 TO 300
MAGNESIUM AND ITS ALLOYS	250 TO 400
BAKELITE	100 TO 150
WOOD	300 TO 400

NOTE: CARBON STEEL DRILLS SHOULD BE RUN AT SPEEDS OF FROM 40 TO 50 PERCENT SLOWER THAN THOSE GIVEN ABOVE.

53—134

Figure 4-16. Cutting foot speeds.

$$\text{RPM} = \frac{4 \times 80 \text{ (the CFS for low carbon steel)}}{0.500 \text{ (the decimal equivalent of } \tfrac{1}{2} \text{ inch)}}$$

$$\text{RPM} = \frac{320}{0.500}$$

$$\text{RPM} = 640$$

After you answer a few more questions, we will take a brief look at some of the ways that the speed can be changed on various types of drill presses.

Exercises (246):

1. How can you prevent work from climbing up the drill bit as it breaks through the lower work surface?

2. Why does a large drill bit require a slower speed than a small one, even though the type of metal to be drilled is the same?

3. You must drill a $\frac{1}{2}$ inch (0.500) in a piece of stainless steel. You select a CFS of 35. What RPM would give you the required CFS?

247. Describe the speed changing techniques for common drill presses.

Speed Changing Techniques. The method that you use to obtain the desired RPM depends upon the type of drill press you are using. Some machines use a gear train located in the drill head to provide the various spindle speeds. You change the speed by positioning speed change levers in accordance with a speed chart which is located on the drill head. You must turn off most machines before moving the levers.

Many machines use a step cone pulley and belt system to provide various speeds. On this type of machine, by moving the belt from one pair of pulley steps to another with the spindle-speed change crank, you can select four spindle speeds. This type of machine must be operating when you move the belt. Also, many of these drill presses have high- and low-speed ranges, which provide four additional speeds. On these drill presses, you select the desired speed range either by moving a shift lever to the high- or low-range position or, on some machines, by positioning an electrical switch to the desired range setting.

Figure 4-1 is an example of a drill press that utilizes the step cone pulley and belt system. If during a speed change attempt, the belt should happen to misalign itself properly, DO NOT attempt to physically reposition the belt until the machine has come to a complete step! Be sure that all the pulley and belt guards are in position before operating the machine.

Most bench-mounted drill presses, such as the one in figure 4-2 must be turned off and the belt physically moved to a different step on the pulley cones. Usually on this type of machine the motor can be swiveled slightly, which shortens the length between the two pulleys and allows the belt to be easily unpositioned. Again, *be sure* the pulleys have stopped rotating before you touch the belt.

The radial drill press is equipped with a gearbox which allows a wide range of speeds. They are selected by positioning two speed change levers on the side of the head (figure 4-3,B). The speed should not be changed while the drill press is in operation. It could easily damage the gears inside the gearbox.

Exercises (247):

1. Describe the step cone pulley speed change system.

2. Describe the process for changing the spindle speed on most bench-mounted drill presses.

3. How is the speed of the radial drill press changed?

4-4. Drill Press Operations

Now, let's take a look at some drill press operations and examine the safety requirements pertaining to drill press work. Also in this section we will discuss drill press installation and maintenance practices.

248. Explain the procedures involved in the preparation for and accomplishment of drill press operations.

Drilling. Any drilling operation can be a success or failure depending on how you prepare the work before you perform the operation. This preparation includes such things as work layout and mounting techniques.

Layout. Many well-performed drill press operations have turned out badly because of improper layout. As we stated in Volume I of this course, accurate layout work is the basis for any good machining operation. However, much of the work you will do on the drill press will be of the type that does not require great accuracy. This causes many people to develop a habit of rushing through drill press work. Eventually this habit leads to unsatisfactory work. No matter what the tolerance is, you should always take time to accurately lay out the hole location and then center punch it so that it can be aligned under the drill press spindle.

Work mounting and drilling. The next step is to mount the work in the drill press. The work should be secured to the table in some way whenever possible.

Use any of the work holding equipment we discussed previously, but be sure that the part cannot work loose during the drilling operation. Be careful to keep the part from tilting under the pressure of clamps or tiedown bolts. Irregular shaped parts might need to be shimmed on one side or the other to prevent the part from tilting. When you mount work in a vise, be sure to tap it down with a soft hammer (brass, plastic, etc.) after the vise has been tightened, because, the movable jaw of a vise has a tendency to raise the work slightly off the work mounting surface.

On some small bench-mounted drill presses, there is no way to mount anything to the table. This type of machine should not be used to drill holes larger than ¼ inch diameter. The work should not be hand held, but should be mounted in a vise. The vise will give you a better hand hold in most cases, and the extra weight of the vise will help prevent the work from spinning if the drill bit should catch in the work.

Once you have prepared the work, you must choose the proper size drill bit and secure it either in the spindle or the drill chuck depending on the type of shank. If it is a taper shank bit, you should tap it into the spindle with a brass or plastic hammer to be sure that it is seated properly. NOTE: Be sure that the tang is aligned with tang-seat before tapping on the bit. If the bit has a straight shank, insert it into the drill chuck and tighten the chuck *with the chuck key*; *not* with your hand as you turn on the machine! CAUTION: Be sure to remove the chuck key from the chuck before you operate the spindle!

If during the drilling operation the drill bit becomes dull, stop the operation and sharpen it. A dull drill bit can cause excessive heat to build up in both the work and the bit and can cause certain metals to work harden to such an extent that further drilling, even with a sharp drill bit, becomes very difficult.

Reaming. Reaming a drilled hole is necessary when the hole must be an exact diameter or when the inner surface of the hole must be particularly smooth. When you must drill and ream a hole, it is best to do it all without moving the setup. In other words, drill the hole (slightly undersize) and then ream it before moving on to another hole or operation. That way you can be sure that the reamer is properly aligned over the hole. The speed used for machine reaming is approximately one-half the normal drilling speed. A cutting lubricant should always be used. Be careful not to use a hand reamer that has a square drive on the end of the shank) in a drill press because it can be ruined easily.

When you must ream a previously drilled hole, you must be careful to align it accurately under the spindle. One of the best ways is to use a drill blank (same length and diameter as the comparable size drill, but without the flutes). Insert the blank in the chuck and then lower the spindle so that the blank enters the hole to be drilled. When the blank extends through the hole, the work can then be carefully secured to the table or in a vise. Check during the securing process to be sure the blank will slide freely in and out of the hole. After the work has been locked in place, the hole can be reamed. This process assures that the axis of the drilled hole is parallel to the axis of the reamer as well as being centered under the spindle.

Other Operations. Countersinking is a fairly simple drill press operation, but it is easy to produce poor quality work. The most common cause of rough and out-of-round countersunk holes is too much speed. If the speed is too high, the countersink will chatter. A cutting lubricant will help assure a smooth countersunk surface.

The main thing to remember when performing a counterboring or spot facing operation is to make sure you have a good solid setup, especially when you must spot face an irregular surface. There is usually a lot of vibration until the teeth of the counterboring tool begins cutting on all sides of the hole. Also, be sure the pilot will fit freely into the hole *before* you start the operation.

Safety is an important part of any machine operation and drill press work is no exception. We will discuss some safety practices pertaining to drill press work in our next objective.

Exercises (248):

1. What should be your prime concern when preparing work for a drilling operation?

2. What procedure should be used to prevent an irregularly shaped part from tipping to one side or the other when it is clamped to a drill press table?

3. Explain how to hold work on a small drill press when it cannot be clamped or secured to the table. Why?

4. Explain how to properly seat a tapered shank drill bit in the spindle.

5. You are drilling several holes in a piece of alloy steel and you notice that the drill bit is not cutting as easily as it should. What should you do and why?

6. Explain the procedure for aligning a drilled hole under the spindle for reaming.

7. Why is it so important to properly secure work prior to a spot facing operation on an uneven surface?

249. Specify safety practices we must follow during drill press operations.

Safety Practices. The most important thing to remember when operating a drill press is that it is a metal cutting machine which is fully capable of causing severe bodily injury if not properly used. Safety glasses should be worn any time you work with a drill press. Check your clothing. Long sleeves should be buttoned or rolled up past the elbow and shirt tails should be tucked in. If a piece of clothing should get caught on a revolving drill bit, you could be drawn into it and injured.

When you turn off the drill press motor, allow the spindle to stop by itself. DO NOT grab the revolving chuck with your hand to stop the spindle more quickly! The slightest burr on the chuck could slice you in several places before you could remove it. Also, you should never pull metal chips away from the cutting action with your hands, and *especially* not when the drill press is operating. When it becomes necessary to remove chips, stop the spindle and remove them with a brush or other suitable tool. If the chips, during drilling, tend to be long and stringy, you should interrupt the feed regularly. This will break the chips before they get too long and will reduce the possibility of your being cut. When long chips get tangled on the bit, they whip wildly and can cut like razor blades.

If a vise or part should break loose during an operation and begin spinning around with the drill bit, DO NOT try to stop it. Instead, hit the motor stop button and get out of the way! It is better to let the drill bit break than to get your hand smashed. This situation usually comes about because of an unsafe act (the work was not properly secured) so if you work safely, it should never happen to you.

Now how about some more questions? Then we will talk about drill press maintenance.

Exercises (249):

1. List the clothing safety practices to be followed during a drill press operation.

2. What safety violation should be avoided when it is necessary to stop the spindle to put a different bit in the drill chuck?

3. Describe the safe way to remove chips from a drill press operation.

4. How can you prevent a drill bit from producing dangerously long chips?

250. Specify machine installation and maintenance techniques.

Installation and Maintenance. The drill press, like all other machine tools, requires some maintenance. When the drill press is installed, it should be leveled and lagged to a solid foundation. This foundation should be solid enough to support the weight of the machine. Great care should be taken in leveling the drill press. If the machine is not properly installed, you cannot hope for the machine to perform with the accuracy for which it was designed. Also, when a radial drill is installed, it should be located in a large area that is free of overhead obstructions so that the arm can be moved freely up, down, or radially.

The oil cups and bearing surfaces should be oiled daily before the drill press is used. Oiling should be progressive, starting at one point and moving around the machine, making certain that all points are lubricated. All surfaces not covered with paint should be lightly oiled to prevent corrosion. The drill press gearbox should receive periodic oiling and oil changes should be made according to the manufacturer's specification. Be sure to check manufacturer's specification for the type, viscosity, and amount of oil to use. Remember that in some cases too much oil can cause severe damage to machine seals.

Before you raise or lower the arm on a radial drill press that hasn't been used for a couple of days, you should wipe the oil film off the column and replace it with fresh clean oil. This is necessary because the oil film attracts dirt and grit which can gouge the column and the arm bushing during raising or lowering. This will eventually lead to seizure of the arm bushing on the column and an *expensive* repair bill.

Exercises (250):

1. What two things must you be most concerned with when installing a drill press?

2. What technique should be used when lubricating the drill press?

3. How can you help prevent the arm of a radial drill press from seizing on the column during raising or lowering?

CHAPTER 5

Lathe Work

THE LATHE IS the most useful machine in the machine shop. More operations can be done on it than on any other machine tool. A machinist can do straight and taper turning, facing, thread cutting, drilling, boring, and spring winding on a lathe. By using various attachments he can also do grinding and milling. In this chapter we will discuss the classification and operation of the lathe, cutting tools, and attachments. All of this information will be used when you perform the various lathe operations.

5-1. Radii and Form Turning

In this section we will look briefly at the various classifications of lathes, and we will review the terminology and grinding procedures for lathe tool bits. These areas of information, along with a short discussion of speeds and feeds, are preliminary to any coverage of the many lathe operations. Radii and form turning are important operations on the lathe, since nearly everything you do on it will involve these operations in one form or another. Therefore we will examine the procedures for radii and form turning in this section.

251. Explain the various classifications of lathes, including size designations, and state the purpose of each.

Lathe Classification. Lathes are divided into three classes: toolroom, engine, and turret. They are quite similar in their general construction and operation, although each is designed for a specific purpose or type of operation. The toolroom lathe is more accurately constructed than the engine lathe and usually has more attachments and accessories, making possible a greater range of precision work. The turret lathe, although similar in construction to both the toolroom and engine lathes, is used primarily for production work. Most lathes are mounted on a base or on legs. Small lathes are usually mounted on a bench or table and are called bench lathes. The addition of casters to the bench makes it possible to move them easily. Bench lathes come in various types and are classified in the same manner as the larger lathes.

The size of the lathe is designated by the maximum diameter of the work that can be swung over the ways, the distance between centers, and the overall length of the bed. The length of the bed is usually designated in inches for smaller lathes and in feet for very large ones. Figure 5-1 illustrates where the size measurements are made.

The engine lathe is designed for general-purpose work and is the most commonly used lathe in Air Force machine shops; however, both toolroom and turret lathes are in use in some AF shops. The main parts of each of the various types of lathes are very similar. The general layout of lathe parts can be seen in figures 5-2 and 5-3.

Exercises (251):

1. Explain the difference between a toolroom lathe and an engine lathe.

2. For what purpose is the turret lathe designed?

3. Explain how the size of a lathe is designated.

252. State the characteristics and purpose of the various lathe tool bit angles and shapes, and specify the procedures for grinding them.

Cutting Tool Angles and Shapes. The shape or contour of a cutting tool has a decided effect on its cutting efficiency. Most tools are hand-ground to shape on a bench or pedestal grinder. Portions of the tool are ground away to leave sharp and strong cutting edges. Except for the rules for grinding the proper rake and relief angles, there are no definite rules to govern the shape of lathe cutting tools. They may be square, pointed, small or large in radius, or irregular in shape. For certain classes of work, the cutting edge may be ground to fit gages of various shapes. Lathe cutting tools may be either right hand (right cut) or left hand (left cut). The cutting edge of a right-hand tool is on the right-hand side when it is viewed from the point end of the tool with the top surface up.

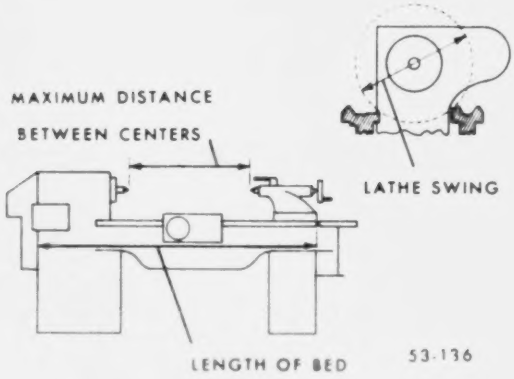


Figure 5-1. Size designation of a lathe.

Relief angles. Relief angles are the angles formed by the intersection of the surfaces below and adjacent to the cutting edge with a plane perpendicular to the base of the tool. There are two types of relief angles, side and end, as shown in figure 5-4. Relief angles provide clearance to prevent the tool from rubbing on the work. They are often referred to as clearance angles. The tool is held in the toolholder at an angle of approximately 14 ½ °. You must take this into consideration when you grind the end relief. For example, if the effective end relief is to be 8°, the active end relief angle must be 22 ½°. The toolholder has no effect on the side relief. Figure 5-5 gives the recommended relief angles for various metals.

Rake angles. Rake angle pertains to the top surface of the tool bit. There are two types of rake angles, back rake and side rake, as shown in figure 5-6. These angles may be positive or negative, or they may have no rake. The toolholder automatically gives a tool a 14 ½ ° effective back rake angle, and you must take this angle into consideration when you grind the tool. For example, to obtain an effective back rake of 16 ½°, you grind the tool with an actual angle of 2°. To obtain an effective angle of 0°, you must grind an angle of 14 ½° off the top of the tool, as shown in figure 5-6. The toolholder does not affect the side rake angle. You measure rake angles from a plane parallel to the base of the tool. Figure 5-5 gives the recommended back rake and side rake angles for various metals.

Cutting edge angles. Cutting edge angles are the angles formed by the cutting edge with the end of the tool (the end cutting edge angle) or with the side of the tool (the side cutting edge angle), as shown in figure 5-7. The end cutting edge angle permits the nose of the tool to make contact with the work, and aids in feeding the tool into the work. This angle is usually 8° to 15°. The side cutting edge angle reduces the pressure on the tool when it begins to cut. A side cutting edge angle of 15° is recommended for rough turning operations.

Wedge angles. Wedge angles are the angles formed by the front relief and back rake or by the side relief and side rake, as shown in figure 5-8. These angles are usually 60° to 65°. However, when you grind the tool to the recommended relief and rake angles, the wedge angles may vary.

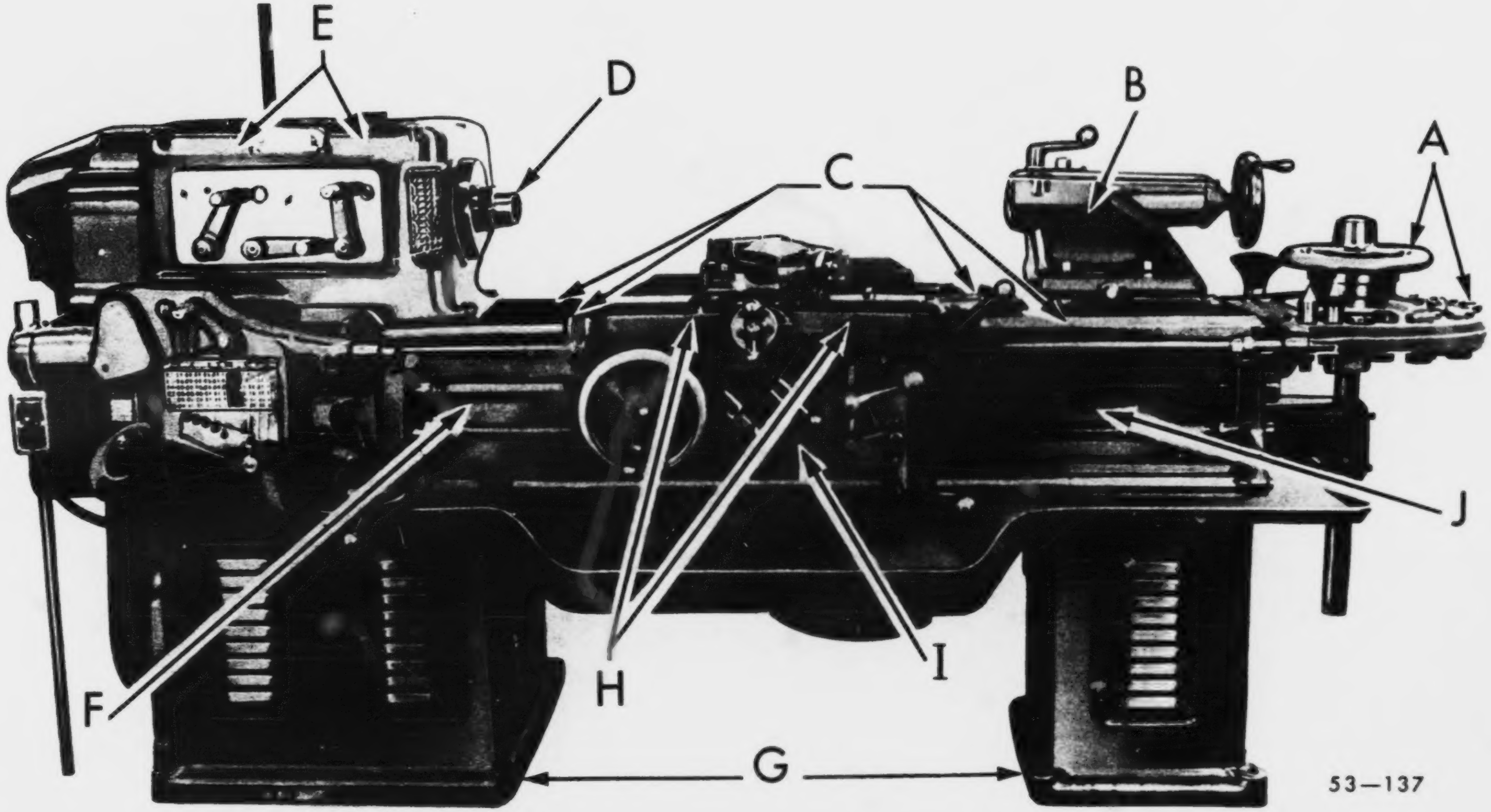
Nose radius. The nose radius strengthens the tip of the tool, helps to radiate the heat generated by the cutting action, and helps to obtain a good finish. You will normally grind a 1/64-inch nose radius on tools ⅜ inch square or smaller, and a 1/32-inch radius on tools from ⅜ inch to 1¼ inches square. Some tools, such as the side-finishing tool, require very little, if any, nose radius. A radius that is too large may cause the tool to chatter because of excessive tool contact.

Chip breakers. Chip breakers are indentations on the top surface of the tool. They prevent the formation of long and dangerous chips. Broken or short chips occupy less space, reduce the amount of heat transferred from the chips to the tool, and permit a better flow of coolant to the cutting edge. Figure 5-9 shows some of the various types of chip breakers. You usually grind chip breakers only on roughing tools.

Grinding Procedures. As we stated previously, lathe tool bits are normally hand-ground on the pedestal grinder. Carbide tool bits, however, are normally ground on special bench grinders because they must be ground on special wheels, usually green colored silicon carbide wheels of 100-120 grain size. Also, the grinding wheels are usually cup-shaped mounted wheels to allow the angles to be ground flat – instead of with the curvature of the wheel as with the pedestal grinding method. Grinding wheels for carbide tools are too soft for efficient grinding of high-speed steel bits and should, therefore, be used only for grinding carbide tools.

For grinding high-speed steel bits, the standard fine grain pedestal wheel is suitable. For best results you should not overheat the cutting edges during grinding. Brown coloration around the edge indicates too much heat, which tends to cause the edge to loose some of its wear resistance. Usually it's better to put at least a slight radius on the point of a tool bit whenever possible. A sharp point will chip easily, even with light cuts, and will not produce as fine a finish as a radiused tool. After a tool bit has been sharpened, you should rub the cutting edges lightly with a fine grained abrasive stone to remove grinding burrs.

Form tools, which are used to cut a specific shape on several like pieces, can be ground to nearly any desired shape, as shown in figure 5-10. However, it is more difficult to grind the proper relief angles because of the irregularly shaped


E
D
B
A
C
H
I
J
F
G
53—137

A. Collet assembly
B. Tailstock
C. Ways
D. Main spindle
E. Headstock
F. Bed
G. Supporting legs
H. Carriage
I. Apron
J. Bed

Figure 5-2. Engine lathe.

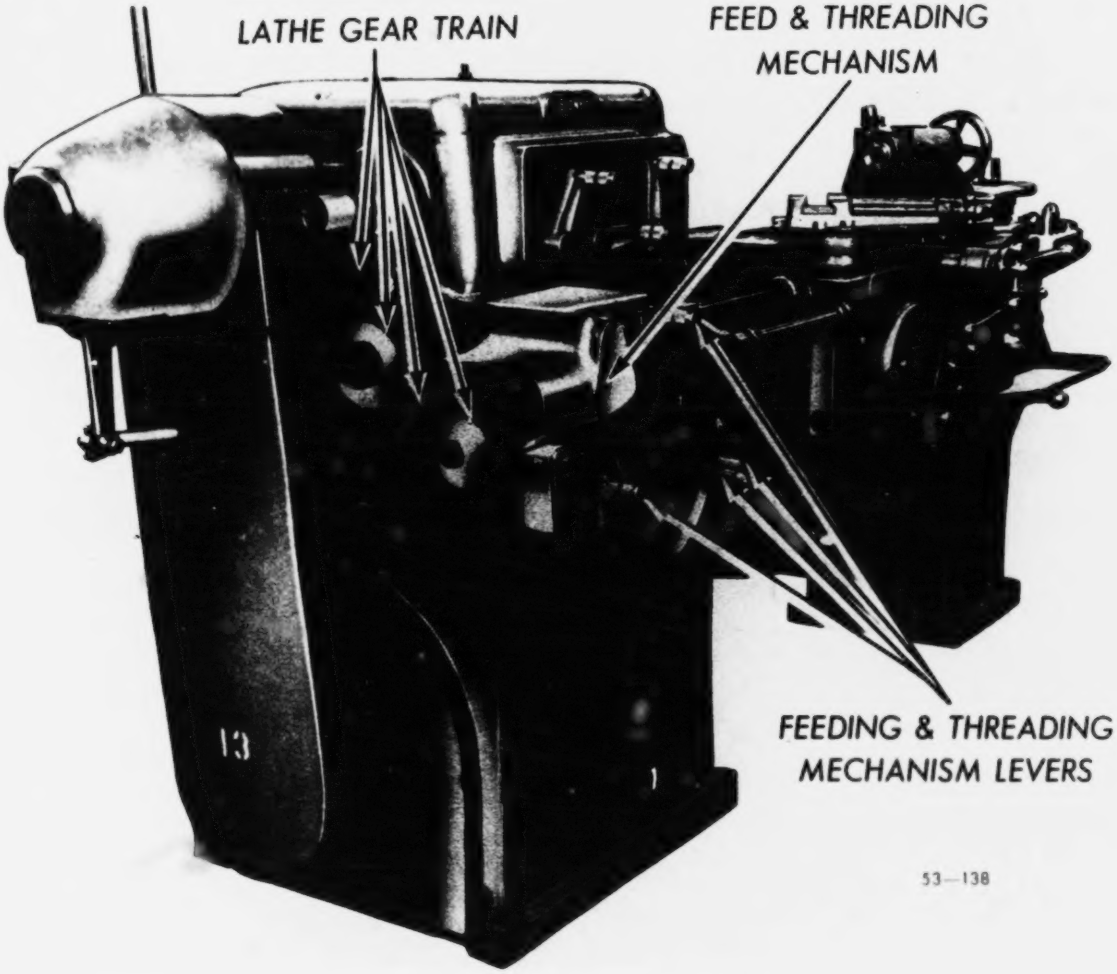

LATHE GEAR TRAIN
FEED & THREADING MECHANISM
FEEDING & THREADING MECHANISM LEVERS
13
53—138

Figure 5-3. Feeding and threading mechanism.

cutting edge. They can be ground on the standard wheel by hand manipulation or they can be ground on a wheel that has had the desired shape cut in its surface.

Exercises (252):

1. Explain how to distinguish a left-hand lathe cutting tool.

2. Where are relief angles located on a tool bit and what is their purpose?

3. What particular tool bit angle, when properly ground, reduces the pressure on the tool when it begins to cut?

4. Explain the advantages of chip breakers on roughing tool bits.

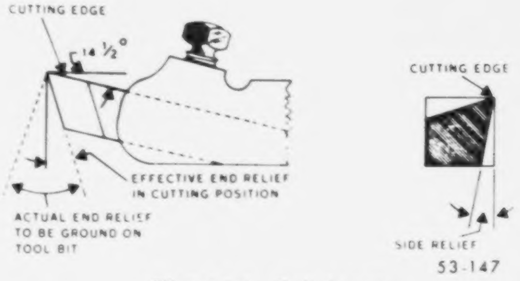

CUTTING EDGE
14 ½°
EFFECTIVE END RELIEF IN CUTTING POSITION
ACTUAL END RELIEF TO BE GROUND ON TOOL BIT
CUTTING EDGE
SIDE RELIEF
53-147

Figure 5-4. Relief angles.

	Side Relief Angle	End Relief Angle	Back Rake Angle	Side Rake Angle
Low-carbon steel	12°	8°	16 1/2°	18°
Medium carbon steel	10°	8°	12°	14°
High-carbon steel	10°	8°	8°	12°
Cast iron	10°	8°	5°	12°
Stainless steel	12°	10°	16 1/2°	10°
Copper	14°	12°	16 1/2°	20°
Bronze	10°	8°	0°	0°
Brass	10°	8°	0°	0°
Aluminum	12°	8°	35°	15°
Monel	15°	13°	8°	14°
Silicon bronze	10°	10°	10°	6°

53-1575

Figure 5-5. Recommended relief and rake angles.

5. When a carbide tool bit must be sharpened or ground, what type of grinding wheel should normally be used?

6. What angles are especially difficult to grind on form tools? Why?

253. Calculate for proper speeds, and select speeds and feeds for lathe work.

Speed. Speed means spindle RPM in lathe work. You can use the formula for selecting drill press speed for lathe work with only a slight modification. Since most lathe work involves the machining of the periphery of a piece of stock, the diameter of the workpiece must be considered. The formula is:

$$\text{RPM} = \frac{4 \times \text{CFS}}{\text{work diameter}}$$

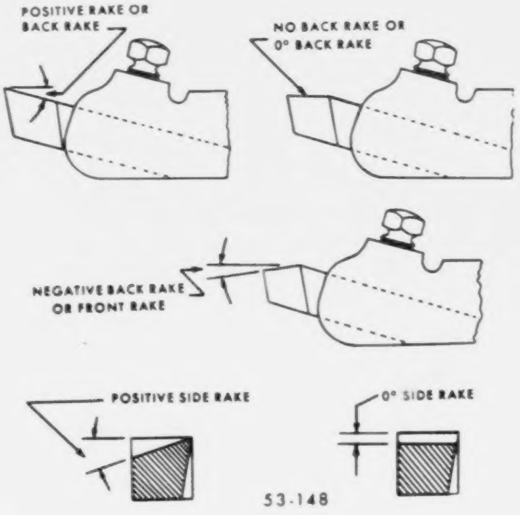
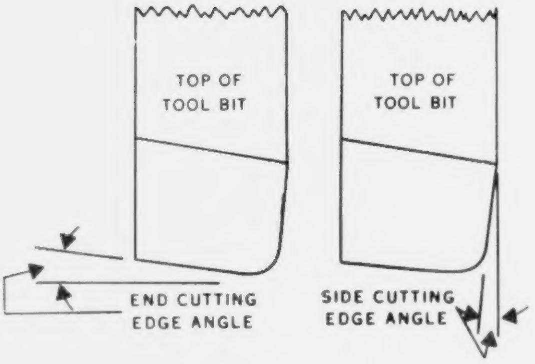

POSITIVE RAKE OR BACK RAKE
NO BACK RAKE OR 0° BACK RAKE
NEGATIVE BACK RAKE OR FRONT RAKE
POSITIVE SIDE RAKE
0° SIDE RAKE
53-148

Figure 5-6. Rake angles.

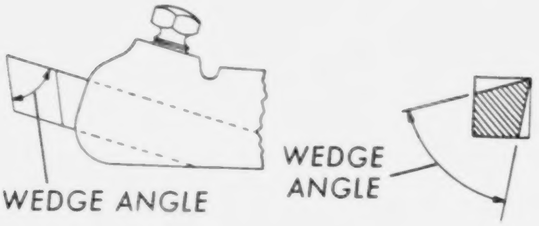


53-149

Figure 5-7. Cutting edge angles.

Work diameter is the diameter actually being machined, and not necessarily the largest diameter of the material. Figure 5-11 gives the recommended CFS (cutting foot speed) for several common materials. For additional information, consult the *Machinery's Handbook* or some other machinist publication. Use the lower value for rough turning and the higher value for finish turning. However, this formula is only a guide. The speed that you actually select should be based primarily on the formula, but you must also consider the following factors:

- The material being machined. Generally, hard materials require a slower cutting speed than do soft or ductile materials.
- Tool material. Normally you will use high-speed cutting tools. Decrease the speed when you use carbon steel tools. Increase the speed when you use carbide and Stellite tools.
- The shape of the tool and the operation being performed. Operations having a great amount of tool and work contact require slower cutting speeds than do general turning operations.
- Feed and depth of cut. Heavy roughing cuts require slower cutting speeds than do light finishing cuts.
- Coolant or cutting lubricant used. Materials which are machined dry require slower speeds than those which are machined with a coolant.
- Power, design, and condition of the machine. You can use higher speeds on heavy, rigidly designed machines which are in good repair than on light-duty or worn machines.



53-150

Figure 5-8. Wedge angles.

Feed. Feed is the distance the tool advances per revolution of the spindle. The feed should be based on the following factors:

- Finish desired. Coarse feeds produce a rough finish; fine feeds, a smooth finish. A feed of 0.025 to 0.035 inch is recommended for rough turning, and a feed of 0.002 to 0.005 inch is recommended for finish turning.
- Work setup. Work that is securely held in a four-jaw chuck or between centers can withstand heavier feeds than can work held in a collet chuck.
- Work diameter and length. Use light feeds when you machine small diameter work or very long work—this to prevent the material from springing away from the cutting tool.
- Tool contact. The greater the amount of tool contact, the greater the pressure exerted on it. This requires a reduction in feed rate.

Exercises (253):

1. What two things must be known to calculate the required RPM of the spindle for a turning operation?

2. What RPM is recommended for turning a 4-inch diameter piece of carbon steel when a CFS of 80 has been selected?

3. What effect does the work setup and tool contact have on the rate of feed that you select?

254. Describe the procedures for turning various size radii and forms on the lathe.

Radii and Form Turning. You may use several methods to machine radii or irregular shapes. The method will depend upon the shape and size of the object and on the number of pieces to be manufactured.

Hand manipulation. The cutting tool moves on an irregular path when you move the carriage and cross-slide simultaneously by hand. You obtain the desired radius or form by coordinating the movement of the carriage and cross-slide as

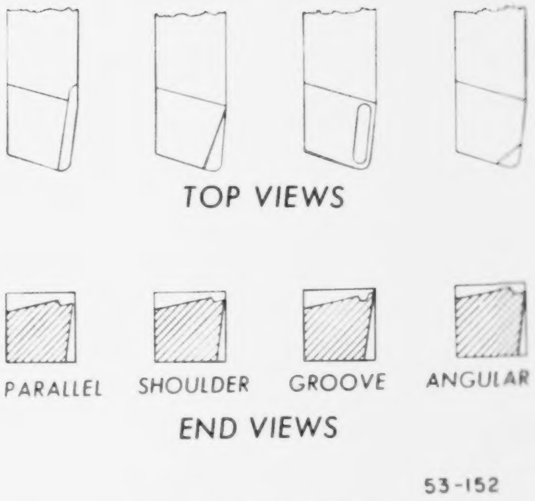


Figure 5-9. Chip breakers.

you observe the cutting action. Patience is a necessity for successful radius and form turning by this method. It also requires more skill than any other method.

Forming tool. The most practical use of the forming tool is in machining several duplicate pieces, since the machining of one or two pieces would not warrant the time spent in grinding the tool. You can use forming tools to machine either concave or convex radii. A concave radius is hollow in shape and a convex radius is spherical or ball shaped. You must operate form tools at much lower speeds than normal turning because the area of tool contact is usually much greater. If the speed is too high, the tool will chatter and produce a rough finish.

Template and pointer. In this method of radius and form turning, you lay out the full-scale form of the work on a piece of thin sheet metal. Then clamp the template to the bed of the lathe. Attach a pointer to the lathe cross-slide and, by hand manipulation, follow the scribed outline on the template to produce the form on the work. You will probably have to finish the form by filing and polishing. Figure 5-12 shows a template and pointer being used to produce a contoured surface.

Radius rod. When you do radius turning using the radius rod, the length of the rod should be equal to the radius that you want to cut. Place the rod between the cross-slide and tailstock, as shown in figure 5-13. The cross-slide will then move in an arc when you apply power feed to the cross-slide. The resistance of the cut holds the rod in position.

Compound rest. When you use this method, the compound rest and tool are swung from side to side in an arc. Form the desired radius by feeding the tool in or out with the compound slide. You can turn either a concave radius by positioning the tool in front of the pivot point, as shown in figure 5-14,A, or a convex radius by positioning the tool behind the pivot point, as shown in figure 5-14,B.

Radius attachment. This attachment may be one of two types. One fits directly on the compound rest and is equipped with a handle to swivel the tool in the desired arc. The other type occupies the place of the cross-slide and compound rest. You can rotate the tool by hand feed or by power if the attachment is geared to the apron of the lathe. Figure 5-15 shows a hand-operated radius attachment being used to machine a convex radius.

In our next section we will discuss another lathe operation: taper turning. But, first, how about a few more questions?

Exercises (254):

1. Describe hand manipulation as a method of turning a radius.

2. If you are using a form tool and find that it chatters badly, what is the probable cause?

3. Describe the setup for a radius turning operation using the radius rod method.

4. How is the hand-operated radius turning attachment mounted on the lathe?

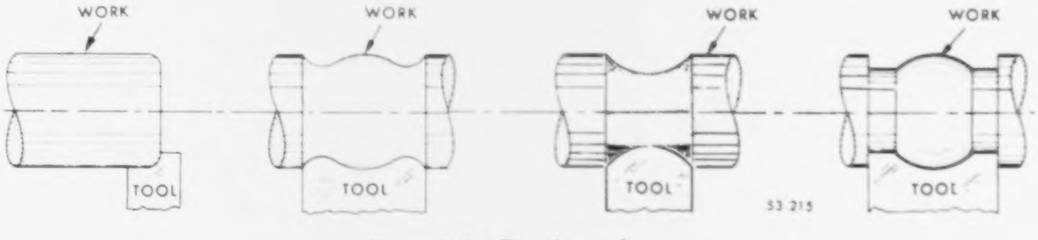
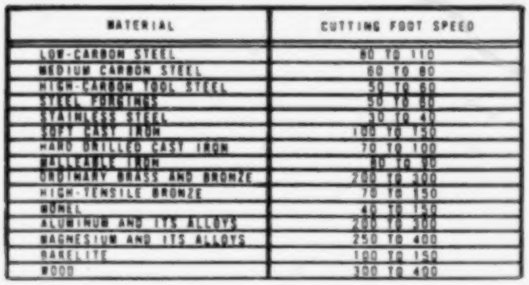


Figure 5-10. Forming tools.



MATERIAL	CUTTING FOOT SPEED
LOW-CARBON STEEL	80 TO 110
MEDIUM CARBON STEEL	60 TO 80
HIGH-CARBON TOOL STEEL	50 TO 60
STEEL FORGINGS	50 TO 60
STAINLESS STEEL	30 TO 40
SOFT CAST IRON	100 TO 150
HARD CHILLED CAST IRON	70 TO 100
MALLEABLE IRON	80 TO 90
ORDINARY BRASS AND BRONZE	200 TO 300
HIGH-TENSILE BRONZE	70 TO 150
MONEL	40 TO 150
ALUMINUM AND ITS ALLOYS	200 TO 300
MAGNESIUM AND ITS ALLOYS	250 TO 400
BAKELITE	100 TO 150
WOOD	300 TO 400

53-1576

Figure 5-11. Recommended cutting foot speed.

5-2. Taper Turning Operations

Many of the tools and parts that you will be using have tapered portions. You must be able to identify the various tapers and be able to machine tapered objects. We will discuss the various standard tapers and their use; the methods of checking tapers; and taper turning by means of the compound rest, tailstock offset, and taper attachment.

255. Explain the characteristics and the uses of various self-holding and self-releasing tapers, including methods of checking them.

The tapers on taper-shanked tools and machine parts, such as twist drills, end mills, reamers, lathe centers, drill chucks, etc., are from various standardized taper series. Standard machine tapers are divided into two classes: (1) self-holding tapers and (2) self-releasing tapers.

Self-Holding (Slow) Tapers. The term "self-holding" is applied to the smaller tapers because the angle of the taper is only 2° or 3° and the shank of the tool is so firmly seated in the socket that there is considerable frictional resistance to any force tending to turn it in the socket. There are several different types of self-holding tapers.

Morse taper. There are eight different sizes of Morse tapers. The taper for each is slightly different, but it is approximately ⅝ inch per foot in most cases. Morse taper-shanks are used on a variety of tools; they are used exclusively on the shanks of twist drills. Spindles of drilling machines and most lathes are constructed to fit a Morse taper.

Brown and Sharpe taper. There are 18 different sizes of Brown and Sharpe tapers. The taper is approximately ½ inch per foot for all sizes except for taper number 10, which has a taper of 0.5161 inch per foot. Brown and Sharpe taper sockets are used for may arbors, collets, and machine tool spindles, and especially for spindles on milling machines and grinding machines.

The ¾-inch-per-foot taper. These tapers come in 11 sizes ranging from 2 to 12 inches in diameter at the large end. They are larger in size, taking up where the Brown and Sharpe and Morse tapers stop in the American Standard Self-Holding Taper Series.

American Standard Self-Holding Taper Series. Twenty-two taper sizes have been selected to make up the American Standard Self-Holding Taper Series. This series contains three sizes of the Brown and Sharpe, all eight sizes of the Morse, and all 11 sizes of the ¾-inch-per-foot taper.

Jarno taper. There are 19 different sizes of Jarno tapers; the taper per foot on all sizes is 0.600 inch. All the dimensions of any size of Jarno taper may be found by using a simple key based on the taper number. The diameter at the large end is as many eights, the diameter at the small end is as many tenths, and the length is as many half inches as indicated by the taper number, thus:

$$\frac{\text{Taper number}}{8} = \text{large diameter}$$

$$\frac{\text{Taper number}}{10} = \text{small diameter}$$

$$\frac{\text{Taper number}}{2} = \text{length of taper}$$

For example, a number 7 Jarno taper has a ⅞ inch large diameter, a 7/10 inch smaller diameter, and a 7/2 inch, or 3½ inches, length. The Jarno taper is used on various machine tools, and especially on profiling and die-sinking machines.

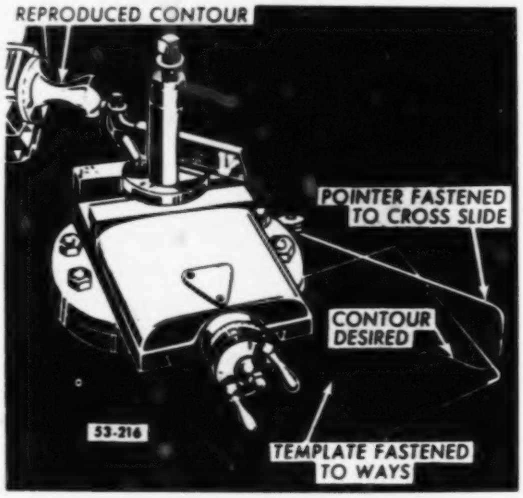


Figure 5-12. Template and pointer.

BEST COPY AVAILABLE

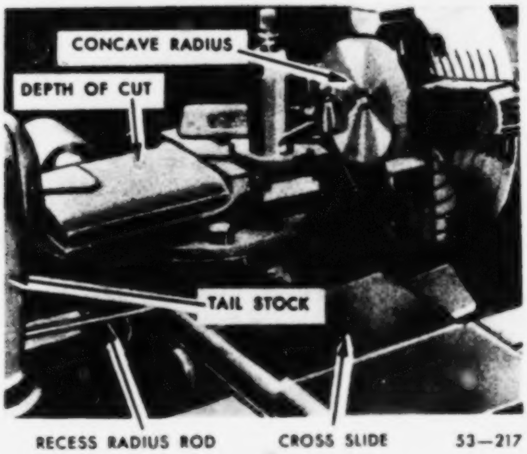


Figure 5-13. Use of a radius rod.

It has also been used for the headstock and tailstock spindles of some lathes.

Taper pins and reamers. Taper pins have a taper of ¼ inch per foot and come in 14 standard sizes. Taper pins are used on assemblies to secure pulleys, gears, and shafts to mating members. Taper pin reamers are used to ream taper pinholes.

Other tapers. There are a number of other tapers, but they are used to such a limited extent that full tables are not given in *Machinery's Handbook*. One, the *Reed taper*, which is used on some lathes, has the same taper as the Jarno taper, 0.600 inch per foot, but it differs in both diameter and length. The Standard Tool Company has two tapers; (1) standard and (2) short. These tapers vary from 0.600 inch to 0.630 inch per foot. The *Sellers taper* has a 0.750-inch-per-foot taper; it has a keyseat the whole length of the taper but no tang.

Self-Releasing Tapers. The term "self-releasing" is applied to the larger tapers to distinguish them from the relatively small self-holding tapers. A milling machine spindle, with a taper of 3½ inches per foot, is an example of a self-releasing taper. The included angle in this case is more than 16°, and the tool or arbor requires a positive locking device to prevent slipping. The shank may be released or removed more readily than the shank of a smaller taper of the self-holding type. There are 12 sizes of American Standard Steep Machine Tapers, all of which have a taper of 3½ inches per foot. NOTE: Detailed information pertaining to exact dimensions of standard tapers may be obtained from machinists' publications, such as *Machinery's Handbook*.

Checking Tapers. You check tapers for accuracy with protractors, tapered ring gages, or micrometers and scribe lines:

- Protractors are used to check tapers when extreme accuracy is not required and when the required taper is given in degrees. Figure 5-16 shows how a protractor head and blade are used to check a steep taper.
- Tapered ring gages are used to check tapers, as shown in figure 5-17. Insert the tapered part in the gage and wiggle it. Any movement of the part in the gage indicates that the taper is incorrect.
- Tapers may be checked by scribing equally spaced lines 1 inch apart on the tapered portion of the work and determining the differences in diameters between lines with a micrometer, as shown in figure 5-18. Careful layout of the lines and alignment of the micrometer will help to insure accurate results when you use this method.
- Internal tapers are generally checked for accuracy with a taper plug gage or with the mating part. Insert the gage in the bored hole and wiggle it. Any movement of the gage indicates that the taper is incorrect.

Exercises (255):

1. Explain the term "self-holding taper."

2. What type of taper would most likely be found on the shank of a drill bit?

3. Explain how the size number on a Jarno taper reveals the large diameter, the small diameter, and the length of the taper. As an example, list the sizes of a number 5 taper.

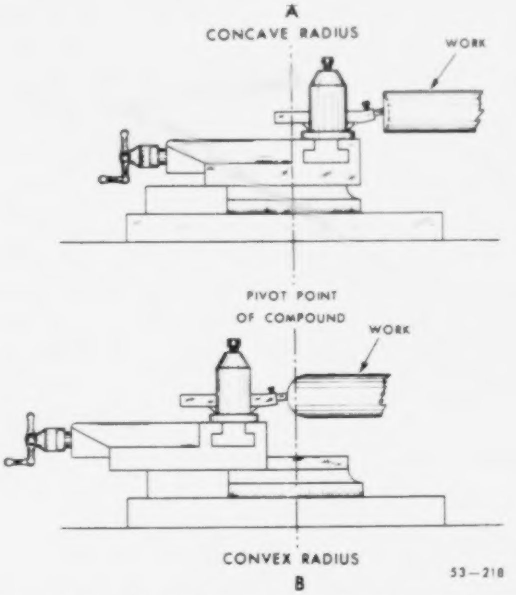


Figure 5-14. Machining a taper with the compound rest.

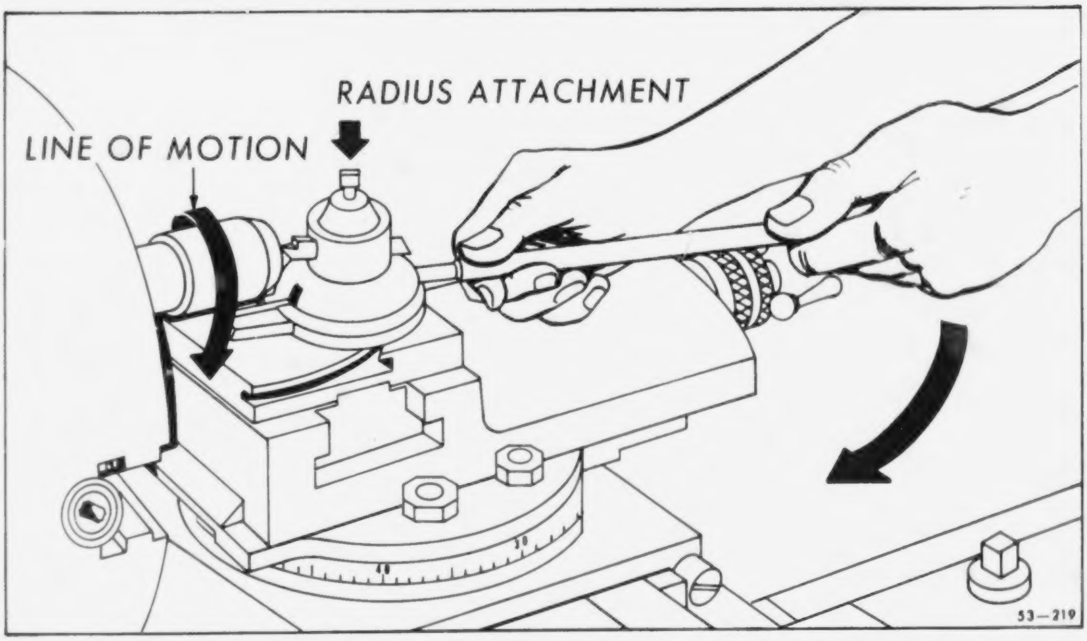


Figure 5-15. Radius turning attachment.

4. Explain the general characteristics of a self-releasing taper.

5. Explain the method of checking a taper with a micrometer.

256. Describe the calculations and the procedures for machining internal and external tapers with the compound rest, including filing and polishing practices.

Taper Turning with the Compound Rest. Both external and internal tapers can be turned with the compound rest. You use the compound rest primarily to machine short, steep tapers, since the length of the taper that can be cut is restricted to the distance the compound can be moved. Position the compound rest at an angle measured from the centerline of the work, figure 5-19,A, or from a line perpendicular to the centerline of the work, figure 5-19,B. For example, the 40° angle in figure 5-19,B, is measured from a line perpendicular to the centerline of the work. In order to machine this angle you must first position the compound rest perpendicular to the centerline, and then move it the required 40°. The graduations on the base of the compound rest swivel represent 1°. You obtain fractions of a degree by estimating the fractional spacing between divisions.

The amount of taper is often designated as taper per inch (TPI) or taper per foot (TPF). Frequently no actual designation of the amount of taper is given at all. The large diameter (LD), the small diameter (SD), and the length of the taper (L of T) are specified, and you must find the TPI before you can set the compound rest properly. To determine the angle at which the compound rest should be set, use the following formulas which apply both to external and internal tapers:

$$\text{TPI} = \frac{\text{LD - SD}}{\text{L of T}}$$

$$\text{Tangent of the angle (tan} \angle\text{)} = \frac{\text{TPI}}{2}$$

Let us apply the formulas above, first, when the TPI is given, and, second, when only the dimensions of a taper are given:

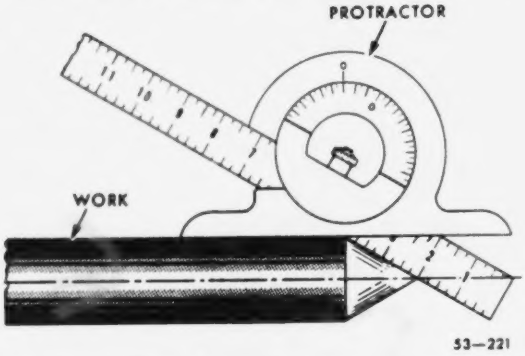


Figure 5-16. Checking taper with a protractor head.

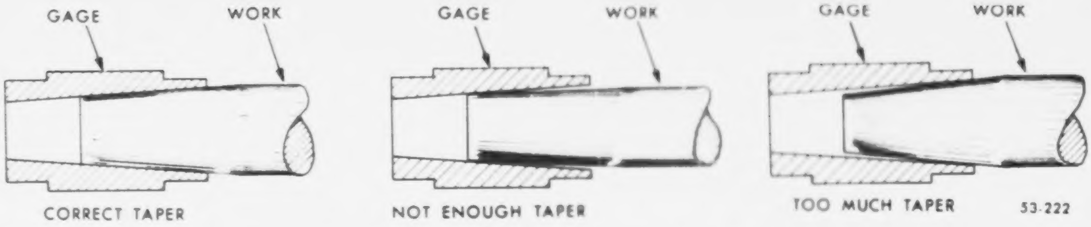


Figure 5-17. Checking taper with a tapered ring gage.

$$\text{Tan} = \frac{\text{TPI}}{2} = \frac{0.800}{2} = 0.400$$

It would now be possible to compute the angle at which to set the compound rest; however, it is more convenient to obtain it from a table of trigonometric functions (often called trig tables). This table, which is several pages in length, may be found in machinists' publications, such as *Machinery's Handbook*, and in trigonometry handbooks. To determine the size of the angle, go down the "tangent" column until you find the tangent of the angle. The nearest value is 0.39997. In the "M" column at the left side of the page opposite 0.39997 you will read 48 minutes. In the upper left corner of the page, above the minutes column, you will read 21° in boldface numerals. Thus 0.39997 is the tangent for 21° 48'. You would set the compound rest for 21 ¾° to machine a taper per inch of 0.800. (If TPF has been specified, it would have been necessary to convert it into TPI by dividing TPF by 12.)

If the dimensions of a taper are given, the computation would be as follows:

Given: LD = 1.250 inches
SD = 1.000 inch
L of T = 0.500 inch

$$\text{TPI} = \frac{\text{LD} - \text{SD}}{\text{L of T}} = \frac{1.250 - 1.000}{0.500} = 0.500$$

$$\text{Tan} = \frac{\text{TPI}}{2} = \frac{0.500}{2} = 0.2500$$

which is the tangent for 14° 2'.

When you machine taper with the compound rest (or any other method), be sure to set the tool bit at center height. This applies to both external and internal tapers. If the tool bit is not at center height, the taper will not be accurate even if the compound rest is set up for the correct angle.

Internal taper turning usually requires the tool bit to be partially obscured while it is in the tapered hole. Be careful to allow room inside the hole to back the tool bit off the surface to bring it back out of the hole. If there isn't enough room and the hole cannot be drilled any larger (because the small taper diameter is close to the hole diameter), then it may be necessary to grind part of the back side of the tool away. If the tool is allowed to rub when you back it off, it will mar the taper surface and possibly break the tool bit.

Most of the tapers that you turn with the compound rest will have to be filed and/or polished. This is because it is hard to attain a smooth finish with this method since the

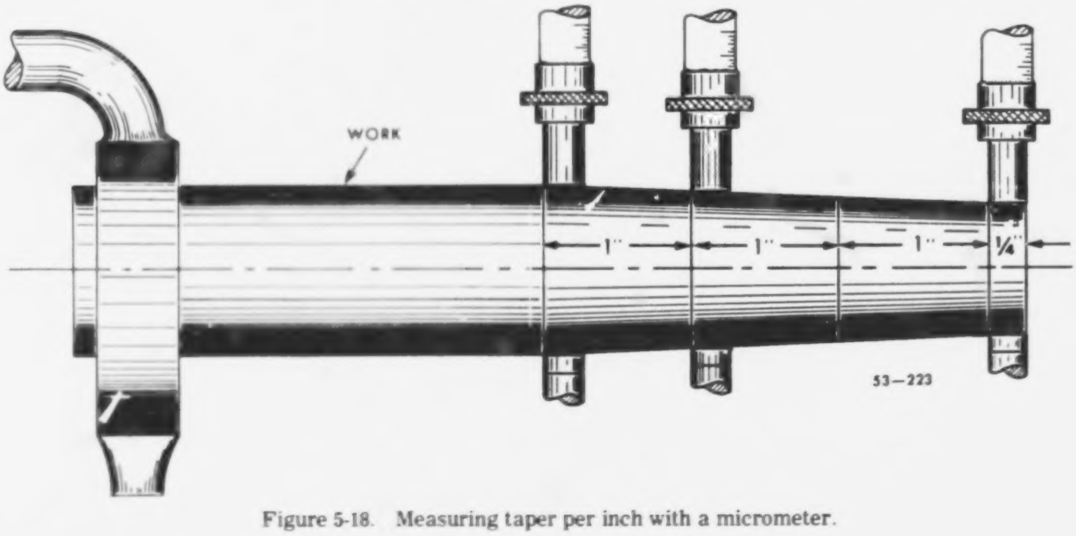


Figure 5-18. Measuring taper per inch with a micrometer.

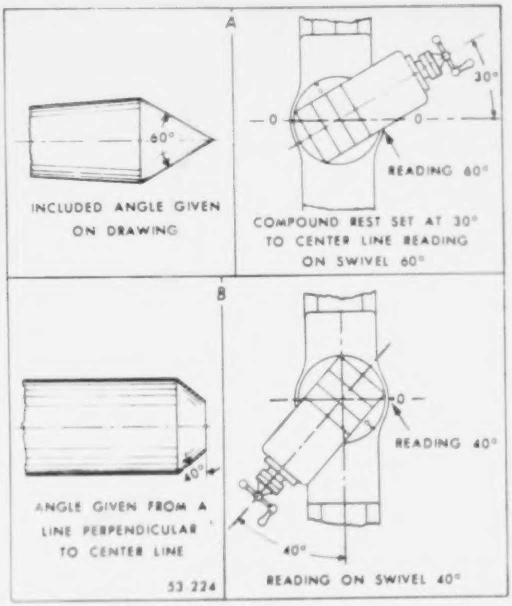

A
60°
INCLUDED ANGLE GIVEN ON DRAWING
30°
0
0
READING 60°
COMPOUND REST SET AT 30° TO CENTER LINE READING ON SWIVEL 60°
B
40°
ANGLE GIVEN FROM A LINE PERPENDICULAR TO CENTER LINE
53-224
0
READING 40°
40°
READING ON SWIVEL 40°

Figure 5-19. Setting the compound rest.

compound rest must be fed by hand. There are a few simple rules to follow if filing and polishing is to be done safely on a lathe.

Filing and polishing lathe work. When you file work which is revolving in the lathe, hold the tip of the file at an angle of approximately 10° toward the tailstock end of the lathe. Hold the file handle with your left hand and hold the tip with your right hand. This prevents you from reaching across a revolving headstock or chuck which is dangerous. Pass the file slowly over the revolving work so that the work turns several revolutions before the stroke is completed. Exert less pressure than for ordinary bench filing, since only a small area of the file and work are in contact when you are filing round work. Release the pressure on the return stroke without lifting the file from the work. Clean the teeth of the file frequently. This prevents the metal that lodges between the teeth of the file from scratching the work or impairing the cutting action of the file. Figure 5-20 illustrates how to hold the file and how to apply it to the work.

CAUTION: Keep your hands and arms clear of the chuck or other work-driving device to avoid injury. NEVER USE A FILE WITHOUT A FILE HANDLE.

The spindle speed for filing metals is four to five times faster than the rough turning speed. If the speed is too slow, there is danger of filing the work out of round.

Figure 5-21 shows how to hold the abrasive strip when you are polishing. Note that the ends of the strip are separated. This prevents the strip from grabbing and winding around the work, which could pull your hand around with it. Move the abrasive strip slowly back and forth along the work to prevent the formation of polishing rings on the work surface. Polishing rings are a series of closely spaced parallel blemishes in the finish around the circumference of the work. The blemishes are burned and scratched areas caused by the loading of the abrasive strip and the trapping of coarse abrasive particles between the work and the abrasive strip. To produce a bright surface, polish the work dry. To produce a dull satin finish, apply oil as you polish.

Polishing requires a very high speed (the recommended surface foot speed is 5000 feet per minute). Therefore, on the average lathe, the highest speed is usually best.

Exercises (256):

1. For what type of taper is the compound rest best suited?

2. Describe the procedure calculating the angle at which to set the compound rest when the dimensions of the required taper are given but the taper per inch is not.

3. If the compound rest was accurately set for a particular taper, but, after the first cut, you discovered the amount of taper was not correct, what would probably be wrong?

4. What condition must you be especially concerned with when turning an internal taper?

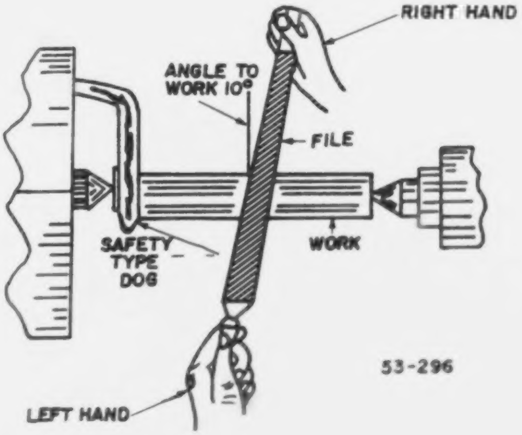


Figure 5-20. Filing work on a lathe.

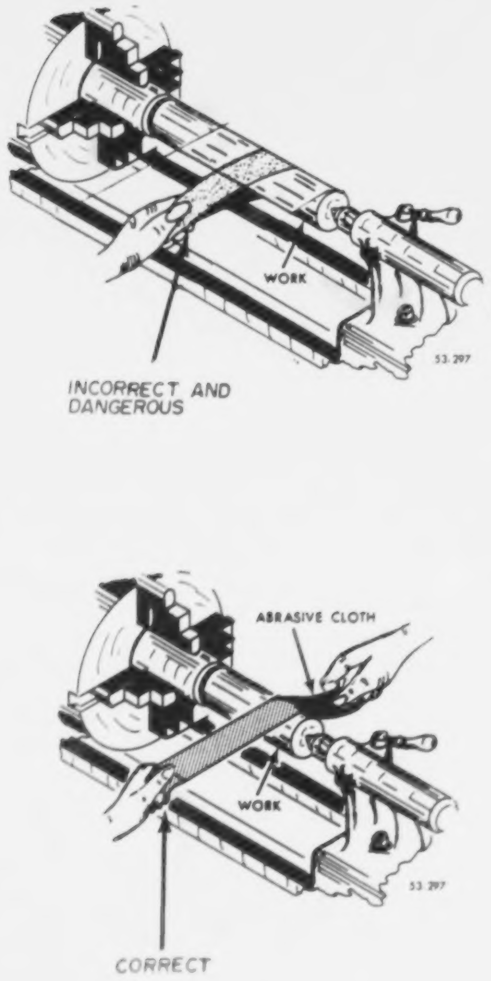

WORK
53-297
INCORRECT AND DANGEROUS
ABRASIVE CLOTH
WORK
53-297
CORRECT

Figure 5-21. Polishing work on a lathe.

5. Describe the correct way to hold a file to file work in a lathe; to hold an abrasive strip for polishing in a lathe.

257. Explain the calculations and procedures for setting up a lathe to machine a taper by offsetting the tailstock.

Taper Turning by Offsetting the Tailstock. You will use the *offset tailstock method* frequently to turn long slow tapers because of the limitations of the compound rest method. Also you will find that every lathe is not equipped with a taper attachment. When you offset the dead center by moving the tailstock out of alignment, the centerline of the work and the line of travel of the turning tool are no longer parallel. A taper will be turned on the work, as shown in figure 5-22. Offset the tailstock, after it has been unclamped, by turning the tailstock lateral adjustment screws. Position the cutting tool at center height in order to turn a true taper.

Calculating offset. You can calculate the offset when you have either (1) the taper per inch and the length, or (2) the included angle and the length:

- When the taper per inch and the length of work are given, you can determine the amount of offset required to cut a taper by using the following formula:

$$\text{Tailstock offset (TO)} = \frac{\text{taper per inch}}{2} \times \text{length of work}$$

Example: To cut a taper having 0.050 TPI, 5 inches in length on a piece of work 10 inches long, as shown in figure 5-23, the tailstock offset would be calculated as follows:

$$TO = \frac{TPI}{2} \times LW$$

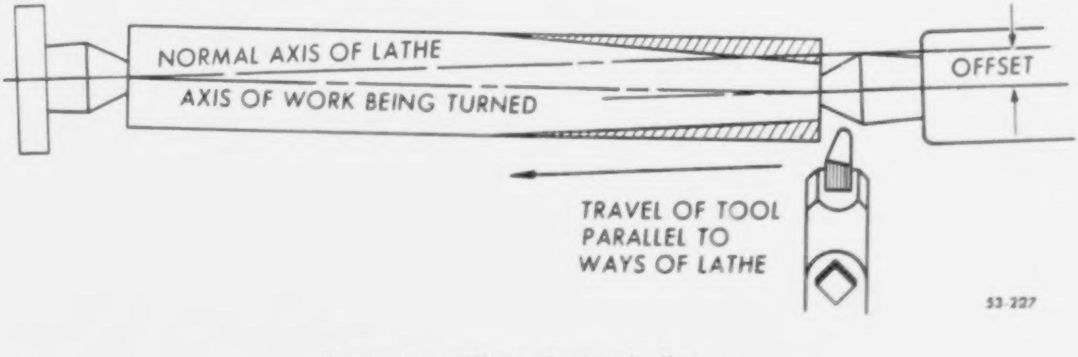

NORMAL AXIS OF LATHE
AXIS OF WORK BEING TURNED
OFFSET
TRAVEL OF TOOL PARALLEL TO WAYS OF LATHE
53-227

Figure 5-22. Effects of tailstock offset.

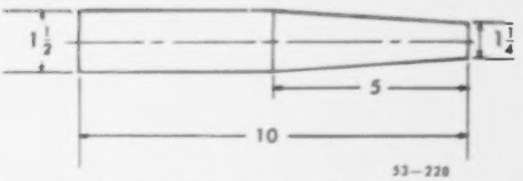


Figure 5-23. Calculating tailstock offset when the dimensions are given.

$$TO = \frac{0.050}{2} \times 10 = 0.025 \times 10$$

$$TO = 0.250 = \frac{1}{4} \text{ inch}$$

- The amount of offset required to cut a taper, when the included angle and the length of work are given, may be determined in the following manner:

(1) First divide the included angle by 2 to determine the angle you must machine:

$$\text{Angle} = \frac{\text{included}}{2}$$

(2) Now, determine the offset by using the following formula:

$$\text{Tailstock offset} = \tan \sphericalangle \times \text{length of work}$$

$$TO = \tan \sphericalangle \times LW$$

Example: To cut a taper with an included angle of 7° on a piece of work 12 inches long, as shown in figure 5-24, the calculations would be as follows:

$$(1)\ \text{Angle} = \frac{7^\circ}{2}$$

$$\text{Angle} = 3\tfrac{1}{2}^\circ$$

$$(2)\ TO = \tan 3\tfrac{1}{2}^\circ \times 12$$

$$TO = 0.06116 \times 12$$

$$TO = 0.7339 = \frac{47 \text{ inch}}{64}$$

NOTE: You should note that the length of taper is not taken into consideration in the foregoing formulas when you calculate the tailstock offset. You use only the overall length of the work and the TPI of the overall length of the work and the included angle of the taper.

When you determine the proper offset for the tailstock, remember that any change in the length of the work between centers will necessitate resetting the tailstock if the taper per inch is to remain constant. A given offset does not give a fixed degree of taper, because the taper increases as the length of work decreases, as shown in figure 5-25.

Measuring offset. You may measure the amount of the tailstock offset by various methods, depending upon the nature of the job. On work that does not require a great degree of accuracy, you may measure the amount of offset by reading the graduations (called cricket marks) on the base of the tailstock, as shown in figure 5-26. Or you may measure the lateral distance between centers with a machinist's rule, as shown in figure 5-27. On work requiring a great deal of accuracy, you may measure the amount of offset (1) with an inside caliper, (2) with the dial test indicator, (3) by using the crossfeed calibrated collar, or (4) by using the cut and try method.

When you check the offset with an inside caliper, bring the toolpost to bear lightly against the side of the tailstock spindle, figure 5-28,A, and then back it away from the tailstock spindle a distance equal to the predetermined caliper setting, figure 5-28,B. Then offset the tailstock until the tailstock spindle again contacts the toolpost, as shown in figure 5-28,C.

When you use the dial test indicator method, mount the instrument on the toolpost, position the indicator plunger to bear lightly against the side of the tailstock spindle, and read the amount of offset on the indicator as you move the tailstock laterally, as shown in figure 5-29.

When you use the crossfeed (cross-slide) calibrated collar method, position the side of the toolpost near the tailstock spindle. Then move the toolpost away from the tailstock spindle with the cross-slide, as shown in figure 5-30,A. This will eliminate the backlash. Now set the cross-slide graduated collar at zero. Move the toolpost toward the tailstock spindle with the compound rest until you feel a slight drag on a strip of paper between the tailstock spindle and the toolpost when you pull on the paper, as shown in figure 5-30,B. Next, using the cross-slide graduated collar to indicate the amount of travel, move the toolpost away from the tailstock spindle a

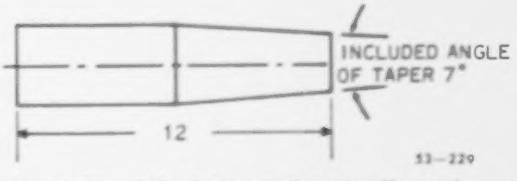


Figure 5-24. Calculating tailstock offset when the included angle is given.

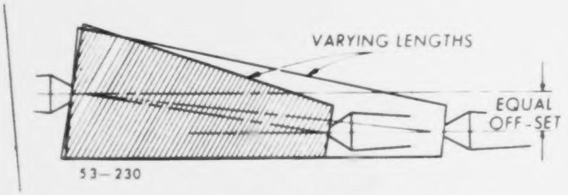


Figure 5-25. Effect of work length on taper.

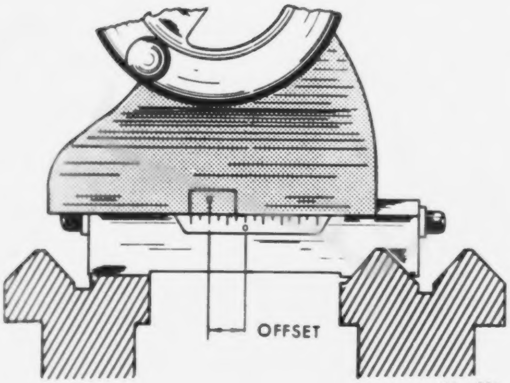


Figure 5-26. Tailstock cricket marks.

distance equal to the desired offset. Thereafter, move the tailstock laterally until you feel a slight on a strip of paper between the tailstock spindle and the toolpost when you pull on the paper, as shown in figure 5-30,C. At this point you have obtained the desired offset.

In the cut and try method, you offset the tailstock an approximate amount and take a trial cut on the work. Then measure the taper per inch, readjust the tailstock, and take more trial cuts until you obtain the desired taper per inch.

While the offset method of taper turning is widely used, it has a number of disadvantages. A slight variation in the length of the work or the depth of center holes will result in a variation in the amount of taper when duplicate pieces are being turned. The center holes of the work do not bear uniformly on the lathe centers; as a result, the center holes may be distorted, and the centers may be scored. Also, you must realign the centers for straight taper turning. The offset method is limited to work held between the centers; therefore only external tapers may be turned. The degree of taper that can be turned is governed by the offset of the tailstock and the length of the work. The range of offset of the tailstock varies from approximately ½ inch on small lathes to 1½ inches on larger lathes.

Exercises (257):

1. Explain how to calculate the tailstock offset when only the taper per inch and the length of work are given.

2. Calculate the tailstock offset to cut a taper where the included angle is 10° and the length of work is 10 inches. The tangent of three different angles is given; choose the correct angle for the calculations: tan 10° - 0.17633; tan 5° = 0.08749; tan 20° = 0.36397.

3. How is the taper per inch affected as the length of the work increases?

4. Explain the procedure for measuring the amount of tailstock offset by the crossfeed graduated collar method.

5. Explain the setup for machining an internal taper with the tailstock offset method.

258. Specify the purpose of the various parts of the taper turning attachment, and state its advantages over the offset tailstock method.

Taper Turning Attachment. The taper attachment is used to machine both internal and external tapers. The length of travel is considerably greater than that of the compound rest; however, the angle to which it may be set is limited. It is more desirable to machine a taper with the taper attachment than with the offset tailstock method because the lathe centers are in alignment. The wear on the centers and center holes is not as great, and duplicate tapers may be machined on pieces of different lengths without changing the taper setting.

Description. The essential parts of the taper attachment, shown in figure 5-31, and the purpose each serves are as follows:

- The carriage bracket (A) is attached to the saddle of the lathe and supports the attachment.
- The guide bar or swivel (B) acts as a guide for the guide block. It is swiveled and set to produce the desired amount of taper.
- The shoe or guide block (C) travels on the guide bar. The guide block is attached to the cross-slide and causes it to move in relation to the angle of the guide bar.
- The guide block base (D) supports the guide bar.
- The clamping screws (E) clamp the guide bar to its base.
- The bed bracket (F) clamps the guide bar to the lathe bed.

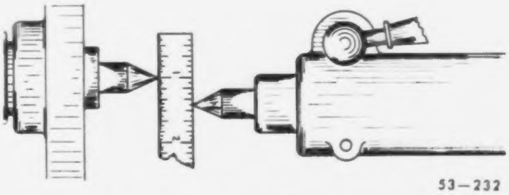


Figure 5-27. Measuring offset with a steel rule.

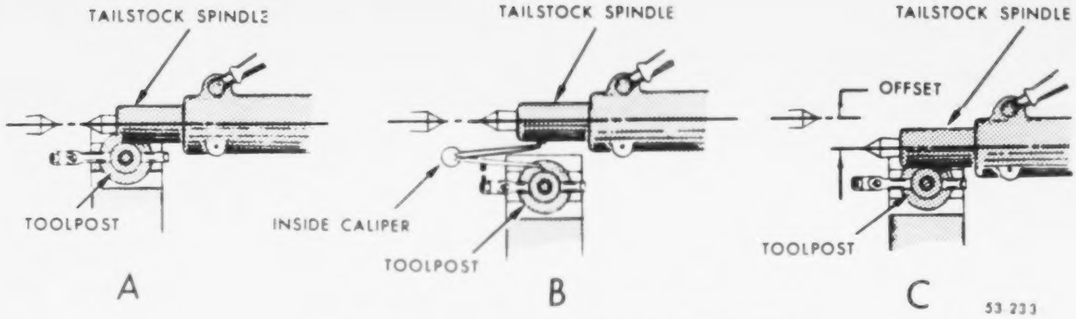


Figure 5-28. Measuring offset with inside calipers.

- The guide block gibs (not shown) take up the wear between the guide block and the guide bar.
- The draw bar (G) connects the cross-slide to the guide block by means of a clamp (H) and relieves the push and pull on the crossfeed screw. This part also prevents backlash.

Exercises (258):

1. What advantages does the taper attachment have over the offset tailstock method of turning tapers?

Match the statements on the right with the appropriate parts on the left. There may be more than one statement pertaining to a particular part.

2. Guide bar _____
3. Guide block _____
4. Carriage bracket _____
5. Draw bar _____
6. Guide block gibs _____

a. Supports the attachment.
b. Takes up wear between the guide block and bar.
c. Connects the cross-slide to the guide block by a clamp.
d. Relieves the strain on the crossfeed screw.
e. Travels on the guide bar.
f. Is swiveled to desired angle.
g. Acts as a guide for the guide block.

259. Explain the operation of the taper turning attachment, including the procedures and calculations for its setup on the lathe.

Operation of the Taper Attachment. Taper attachments vary in design with different manufacturers; however, the operation of all of them is basically the same. Swivel the guide bar to the desired degree of taper and clamp it in position, as shown in figure 5-32. As the carriage travels along the ways, the guide block will slide on the guide bar, causing the draw bar to push the cross-slide toward, or pull it away from, the work. This, in turn, will cause the tool to move in a plane parallel to the guide bar, and a taper will be machined on the work.

On taper attachments that are not equipped with a draw bar, the push or pull is directly on the crossfeed screw, and there will be a certain amount of lost motion or backlash between the crossfeed screw and the nut. If backlash is not eliminated, a straight portion will be turned on the work. The backlash may be eliminated by one of two methods, as follows:

- Move the carriage and tool slightly past the start of the cut, then return the carriage and tool to the start of the cut.
- Move the cross-slide and the tool in the same direction in which the taper runs; i.e., make the last movement of the cross-slide away

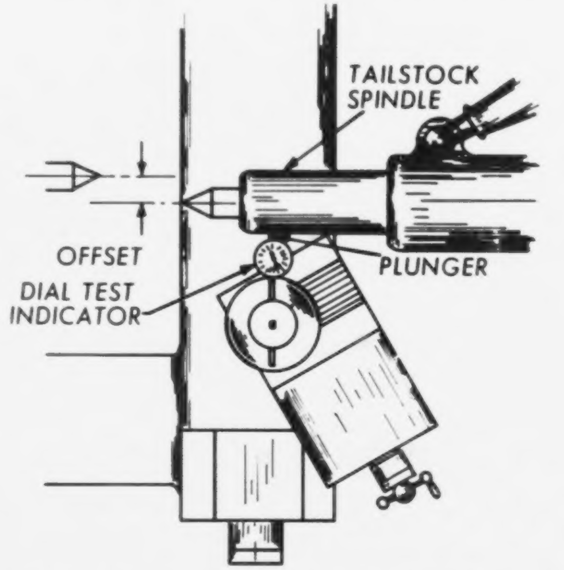


Figure 5-29. Measuring offset with a dial indicator.

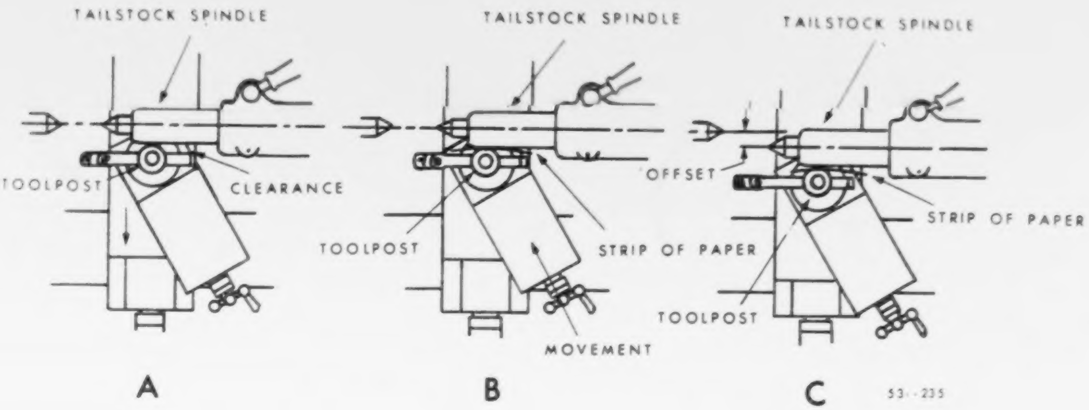
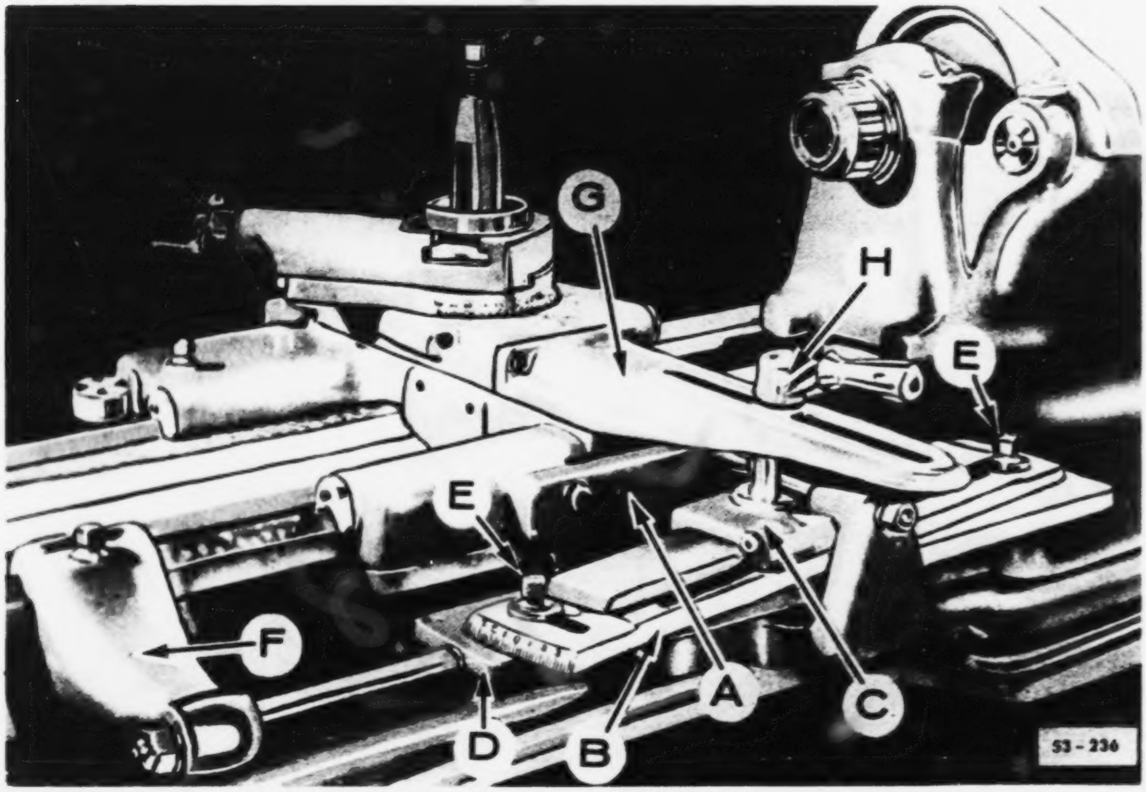

TAILSTOCK SPINDLE
TOOLPOST
CLEARANCE
A
TAILSTOCK SPINDLE
TOOLPOST
STRIP OF PAPER
MOVEMENT
B
TAILSTOCK SPINDLE
OFFSET
STRIP OF PAPER
TOOLPOST
C
53--235

Figure 5-30. Measuring offset with the cross-slide graduated collar.


G
H
E
E
F
A
C
D
B
53 - 236

A. Carriage bracket
B. Guide bar
C. Guide block
D. Guide block use
E. Clamp screw
F. Bed bracket
G. Draw bar
H. Clamp

Figure 5-31. Taper attachment.

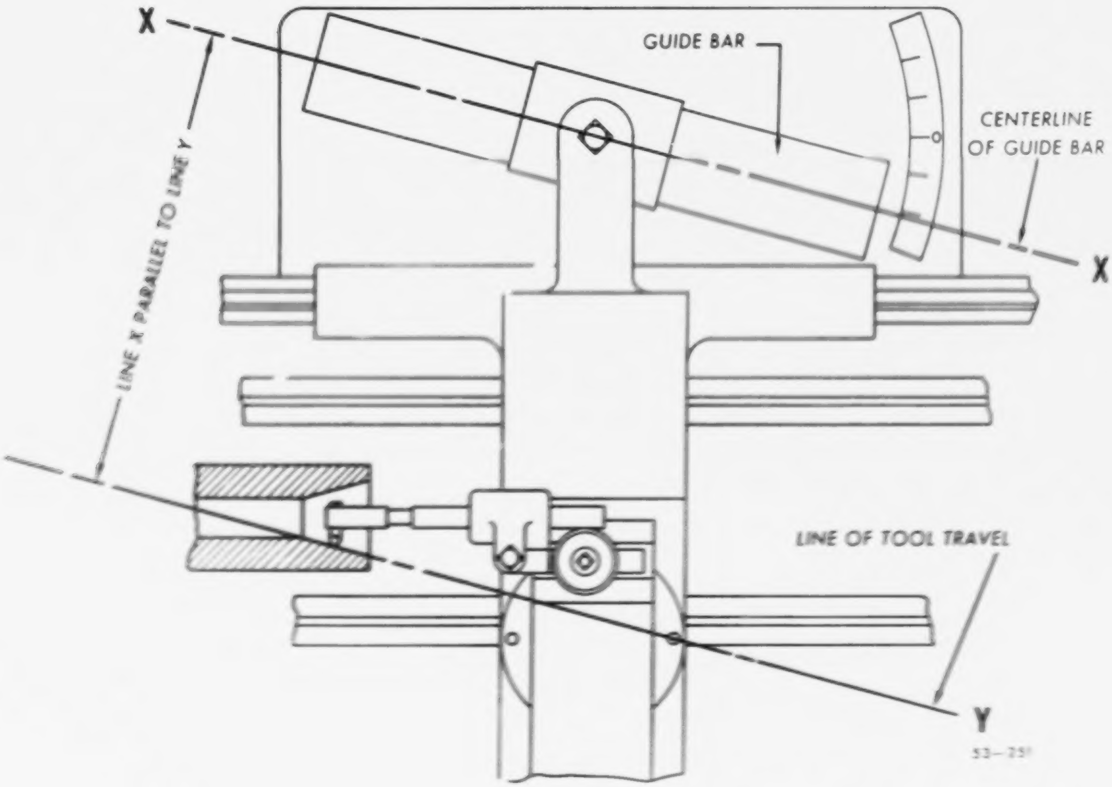


Figure 5-32. Aligning taper attachment guide bar.

from you when the small end of the taper is toward the headstock, or toward you when the large end of the taper is toward the headstock. Any further movement of the carriage, other than in the direction of the cut, will automatically put backlash in the system.

Taper attachments equipped with a drawbar do not have backlash. The drawbar connects the cross-slide directly to the guide block and takes the push and the pull off the crossfeed screw and the nut. You set the compound rest at a right angle to the ways and take the depth of cut with the compound rest, since the drawbar locks the cross-slide directly to the guide block, the cross-slide cannot be moved with the crossfeed screw. The guide bar, which is swiveled and set to give the desired taper, is graduated in taper per foot on one end and degrees of taper on the opposite end, as shown in figure 5-33. To set the guide bar for the proper taper when the taper per inch is given, multiply by 12 to get the taper per foot and set the graduated scale to the nearest fractional setting.

Setup calculations. Let us assume that you are setting up a taper attachment prior to machining a drill sleeve for which a number 2 Morse external taper is specified. What setting would you use for the first trial cuts if you had decided to use the taper-per-foot graduations? The degree graduations? You can determine the taper-per-foot setting in the following manner: Find the taper per inch of a number 2 Morse taper in a machinist publication, such as *Machinery's Handbook*. (TPI =0.04995.) Convert the taper per inch into taper per foot:

$$\begin{aligned} \text{TPF} &= \text{TPI} \times 12 \\ \text{TPF} &= 0.04995 \times 12 \\ \text{TPF} &= 0.5994 \end{aligned}$$

Convert the decimal to a fraction, using a decimal equivalent table:

$$0.5994 = \frac{19}{32} \ (0.5937)$$

Set the taper attachment to obtain a 19/32-per-foot taper. NOTE: Taper attachments are often graduated in $\frac{1}{8}$-inch-per-foot increments; therefore you may have to estimate settings that fall between the $\frac{1}{8}$-inch graduations. You can obtain sufficient accuracy for the first trial cuts by setting the taper attachment for a taper of slightly less than $\frac{5}{8}$ inch per foot.

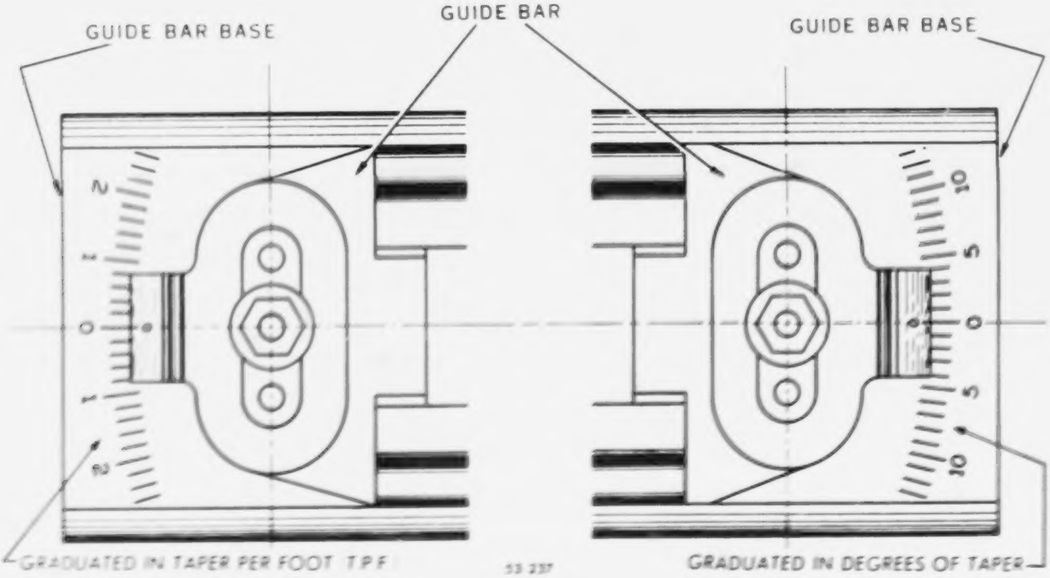

GUIDE BAR BASE
GUIDE BAR
GUIDE BAR BASE
2
1
0
1
2
10
5
0
5
10
GRADUATED IN TAPER PER FOOT TPF
53 237
GRADUATED IN DEGREES OF TAPER

Figure 5-33. Guide bar graduations.

If you had decided to use the degree graduations, you would determine the degree setting in the following manner:

Find the tangent of the angle ($\tan \angle = \frac{\text{TPI}}{2}$

$$\tan \angle = \frac{0.04995}{2}$$

$$\tan \angle = 0.02497$$

Look in a table of trigonometric functions and find the angle represented by the tangent you have calculated.

Tan 0.02497 = 1° 26'

or

Approximately 1½°

NOTE: The degree graduations on most taper attachments represent the included angle of the taper. Therefore you would set the taper attachment to indicate twice the angle you have calculated, or 3°. This concludes our study of tapers and lathe taper turning operations. After you try your hand at a few more questions, we will begin our next section concerning lathe parting operations.

Exercises (259):

1. Describe the way that the cross-slide is moved by the taper attachment when it is set up to cut a taper.

2. If you are machining a taper with the small end near the tailstock and situated in such a way that you cannot move the tool far enough past the end of the cut to remove the backlash by that method, explain how it can be removed.

3. You must machine a taper with a 0.0625 TPI. You decide to use the taper-per-foot graduation on the taper attachment guide bar. What setting should you use?

5-3. Parting Operations

Parting, also called cutting off, is the process of cutting a groove around revolving work in order to sever part of it from the piece held in the lathe. Parting is used (1) to cut off parts that have already been machined in the lathe, (2) to cut off tubing and bar stock to required lengths, (3) to machine necks and grooves in material, and (4) to cut off material that would be impractical to saw in power hacksaws. In this section we will discuss parting tools and the parting operation on the lathe.

260. Describe the types of parting tools, and explain parting tool geometry.

Parting Tools. Three types of tools are commonly used for parting: the (1) solid, forged type; (2) high-speed steel cutter blades which are held in patented toolholders; and (3) tools ground

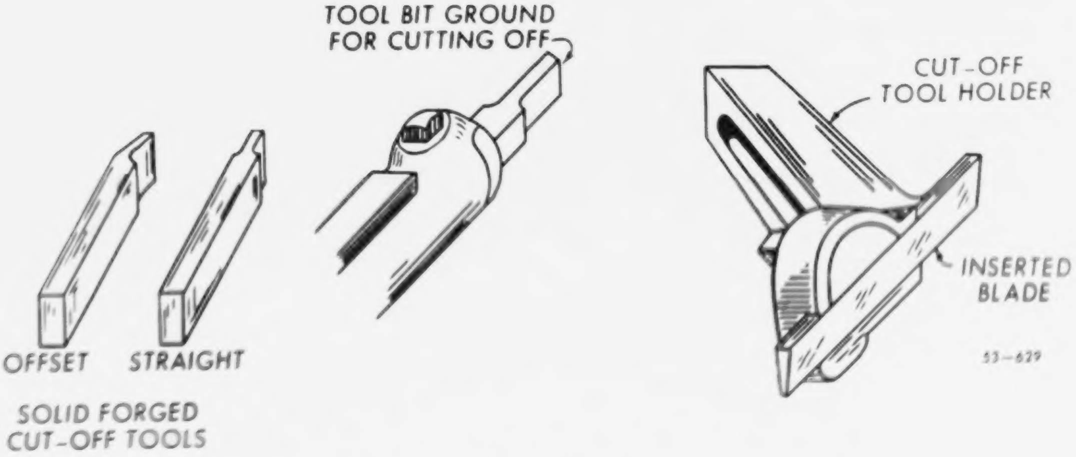


Figure 5-34. Types of parting tools.

to shape from tool bits. Examples for these three types are shown in figure 5-34.

The solid, forged-type parting tool is forged from either carbon steel or high-speed steel and is ground to meet the requirements of the job at hand. It may be either straight or offset. This tool is being rapidly replaced by the inserted cutter blade-type parting tool.

The inserted blade-type parting tools are made in a variety of sizes and are held in special toolholders. The toolholders are available in straight and offset types, as shown in figure 5-35. You can sharpen the blades repeatedly and replace them when they are too short to hold safely in the toolholder. Some blades are manufactured with the necessary flank and side relief angles ground in them; only the end relief is ground when you sharpen them. Flank relief is the clearance ground on both sides of the parting tool behind the cutting edge. Flank relief helps to prevent the sides of the parting tool from contacting the sides of the groove that is formed during parting.

Parting tools ground from tool bits, as shown in figure 5-36, are used mostly on small work. The cutting edge may be ground straight or offset, as shown in figure 5-36, A and B. The top of the tool is ground down, as shown in figure 5-36,C, to eliminate the excessive back rake created by the toolholder.

Parting tool geometry. The general shape of parting tools is the same for all three types. They are ground so that the cutting edge is the widest part of the tool. Grind both sides of the tool with 1° to 2° of back clearance of flank relief, figure 5-37,A, and 2° side clearance, figure 5-37,B. Back rake is usually eliminated. The end relief should be approximately 15° for parting soft metal, such as brass (figure 5-37,C). For steel and harder metals a back rake of about 5° gives free cutting action and helps to curl the chip, and the end relief should be approximately 10° (figure 5-37,D). In order for the tool to have maximum strength, the length of the cutting portion of the blade should be only slightly greater than half the diameter of the work to be parted.

Exercises (260):

1. List and briefly describe the three common types of parting tools.

2. Explain flank relief and side clearance as it pertains to parting tools and state the recommended angles for each.

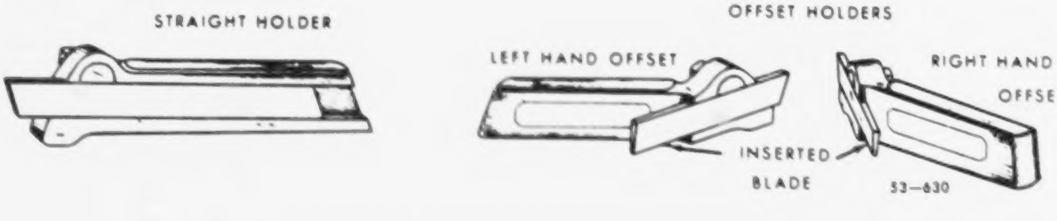


Figure 5-35. Inserted blade parting tools and holders.

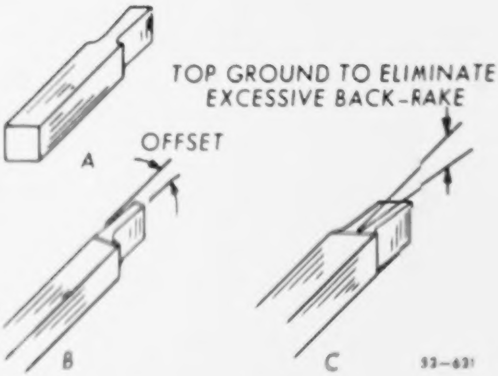


Figure 5-36. Parting tool ground from tool bits.

261. Explain the lathe parting operation, including setup and safety precautions.

Parting Tool Setup and Operation. Work to be parted should be held in a chuck, preferably the four-jaw type, with the point at which the parting is to occur as close as possible to the chuck jaws. Always make the parting cut at a right angle to the centerline of the work and feed the tool into the revolving work with the cross-slide until the tool completely severs the work. A power feed of approximately 0.002 inch per revolution may be used. However, you have better control of the tool if you feed it by hand.

Cutting speeds for parting are usually somewhat slower than turning speeds. You should use a feed that will keep a thin chip coming continuously from the work. If chatter occurs, decrease the speed and increase the feed. If the tool tends to gouge or dig in, decrease the feed.

The parting tool should be at center height. It must be square to the work axis to prevent the tool from binding in the cut.

On large diameter jobs where there is danger of the tool binding in the groove, you should use the step-parting method. In step parting you feed the tool into the work a short distance. Then you withdraw the tool from the groove, move the carriage slightly to one side, and feed the tool in again. This leaves only one side of the tool in contact with the groove and prevents binding. Take alternate cuts until the work is cut off.

The length of the portion to be cut off may be measured by placing the edge of a steel rule against the side of the work and the end of the rule against the side of the parting tool. Move the carriage until the desired length is obtained. You may also align the parting tool to a layout line scribed on the work. NOTE: Always lock the carriage in position to prevent it from moving while you are taking the parting cut. CAUTION: Never attempt to catch the piece that has been parted off. It will probably be hot and it will have dangerous burrs and sharp edges on it. Now it's time for some more questions and then we will begin a section on threading operations on the lathe.

Exercises (261):

1. Explain the parting tool setup.

2. What is the probable cause of the tool gouging into the work during a parting operation?

3. Why shouldn't you try to catch a piece that has been parted off?

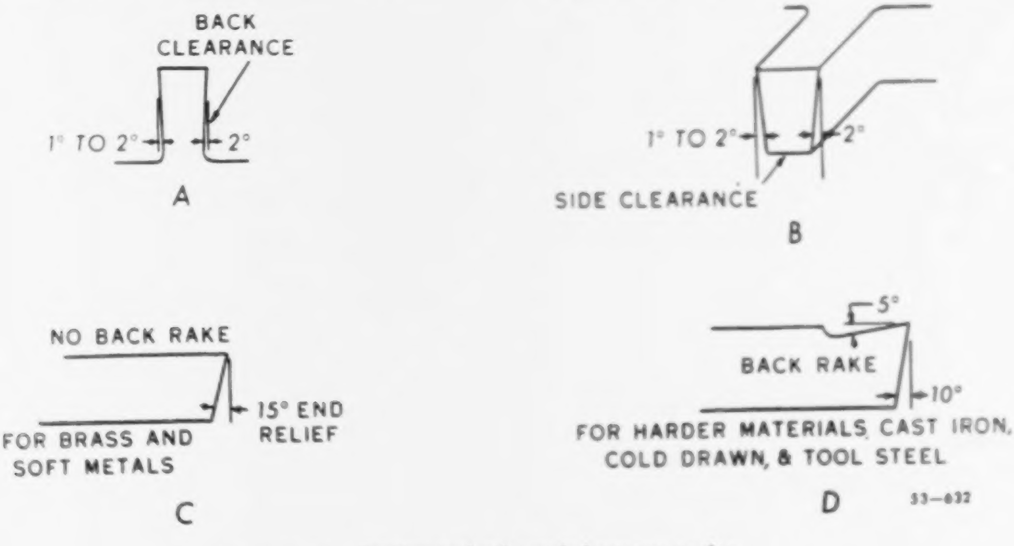


Figure 5-37. Parting tool rake and clearance angles.

5-4. Threading Operations

Cutting threads on the lathe will be a big part of your work as a machinist. There are many types of threads and many types of thread cutting operations any one of which you may be called on to machine or perform. In this section we will examine thread types and terminology and threading procedures for left-hand, multiple lead, pipe, acme, square, and metric threads plus tap and die operations on the lathe.

262. Interpret thread terminology and designations.

Threading Terms. To be able to understand threads and threading operations, you must know the meaning of certain terms. Figure 5-38 will help you to understand the following definitions.

- Thread. A thread is the ridge or projection remaining after a uniform, helical groove is cut on the outside or inside of a shaft or hole.
- Threads per inch. Threads per inch is the number of threads per inch measured parallel to the thread axis. It is used in conjunction with the outside diameter to designate the size of the thread. For example, ¾-10 indicates 10 threads per inch on a piece of stock ¾ inch in diameter.
- Thread angle. The thread angle is the angle formed by the intersection of the two sides of the thread groove.
- Helix angle. The helix or lead angle is the angle formed by the inclination of the thread and a plane perpendicular to the thread axis.
- Major diameter. The major diameter is the largest diameter of an external or internal thread.
- Pitch diameter. The pitch diameter is the diameter of an imaginary cylinder that is concentric with the thread axis and whose periphery passes through the thread profile at the point where the width of the thread and the thread groove are equal. The pitch diameter is the diameter which is measured when the thread is machined to size. A change in pitch diameter changes the fit between the thread being machined and the mating thread.
- Nominal size. The nominal size is the size which is used for identification. For example, the nominal size of a ½-20 thread is ½ inch, but its actual size is slightly smaller to provide clearance.
- Actual size. The actual size is the measured size.
- Basic size. The basic size is the theoretical size. The basic size is changed to provide the desired clearance or fit.
- Pitch. Pitch is the distance from a point on a thread to a corresponding point on the next thread measured parallel to the thread axis.
- Lead. Lead is the lateral distance a thread moves per revolution. On a single-lead thread, the lead and the pitch are identical; on a double-lead thread, the lead is twice the pitch; on a triple-lead thread, the lead is three times the pitch; etc.
- Crest. The crest of a thread is the top surface that joins the two sides of the thread.
- Root. The root of a thread is the bottom surface that joins the two sides of adjacent threads.
- Truncation. Truncation is the perpendicular distance from the crest of a thread or the root of a thread and the point of intersection that would be created if the sides of the thread were extended to form a sharp "V."
- Crest clearance. Crest clearance is the perpendicular distance between the crest of a thread and the root of a mating thread when it is engaged.
- Thread depth. Thread depth is the perpendicular distance between the crest and root of a thread.
- Width of a basic crest or a basic root. The width of a basic crest or a basic root of an American Standard Unified thread is one-eighth of the pitch.

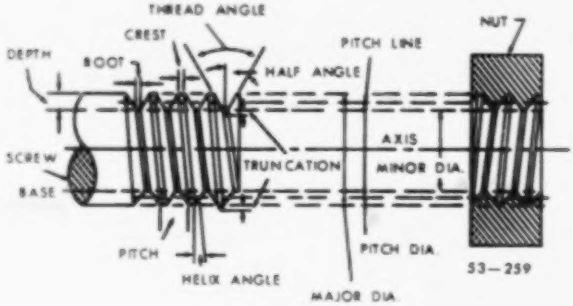


Figure 5-38. Thread parts.

Thread Designation. A thread is designated according to the nominal size, the number of threads per inch, the series symbol, and the class symbol, in that order. For example, the designation ¼-20 UNC-3A is explained as follows:

¼ = nominal thread diameter
20 = number of threads per inch
UNC = series (Unified coarse)
3 = class
A = external thread

Unless the designation LH (left hand) follows the class designation, the thread is assumed to be a right-hand thread. An example of the designation for a left-hand thread is: ¼-20 UNC-3A-LH. The symbols used to identify the thread series are these:

UNC – Unified coarse
UNF – Unified fine
UNEF – Unified extra fine
UNS – Unified special

Constant pitch series are identified by the number of threads per inch of the series, followed by the Unified symbol (UN), such as 8UN or 32UN. The same symbols are used to identify the old National Thread System, except that the letter U is omitted. For example: ¼-20NC-2.

The class symbol designates the tolerance grouping to apply to a given thread. Each size of thread has three classes of fit, which are identified as class 1, 2, or 3. In addition to the numerical designation, the letter A indicates an external thread class and the letter B indicates an internal thread class. The tolerances for class 1 threads are greater than those for class 2, and the tolerances for class 2 threads are greater than those for class 3 threads. Any desired fit can be obtained by using an external thread of one class with an internal thread of another class, such as a 2A bolt and a 3B nut. Complete listings of Unified threads and the dimensions of the threads for each class can be found in machinists' publications, such as the *Machinery's Handbook*.

Exercises (262):

1. What is the helix angle of a thread?

2. What is the difference between pitch and the pitch diameter?

3. Interpret the meaning ¼-28UNF-3B.

263. Describe the various methods of thread measurement, including calculations for using the three-wire method.

Thread Measurement. Thread measurement is necessary to insure that the thread and its mating part will fit properly. It is important that you know the various measuring methods and the calculations which are used to determine the dimensions of threads.

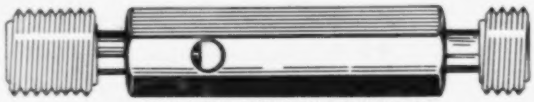
Several methods can be used to check threads. The one which you will use will depend upon the accuracy required for the particular thread which you are machining.

Mating part. The use of a mating part is a common practice when average accuracy is required. The thread is simply machined until the mating part will assemble. A snug fit is usually desired, with very little play, if any, between the parts.

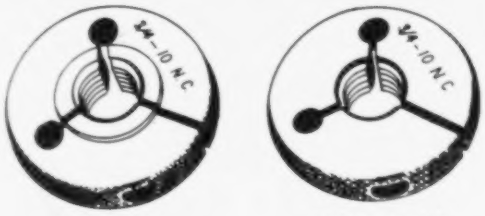
Thread gages. Go and no-go gages, such as those shown in figure 5-39, are often used to check threaded parts. The thread should fit the go portion of the gage; but should not screw into the no-go portion. The threaded plug gage is one of the most exact means of checking internal threads.

Thread calipers. Thread calipers are similar to common calipers, except that the legs are ground to the shape of a thread. They are used to measure from a finished thread to the thread being machined and are fairly accurate.

Thread micrometers. Thread micrometers are used to measure the pitch diameter of threads. They are graduated and are read in the same manner as are ordinary micrometers. However, the anvil and spindle are ground to the shape of a thread, as shown in figure 5-40. Thread micrometers come in the same size ranges as ordinary micrometers: 0 to 1 inch, 1 to 2 inches, etc. In addition, they are available in various pitch ranges. The number of threads per inch must be within the pitch range of the thread

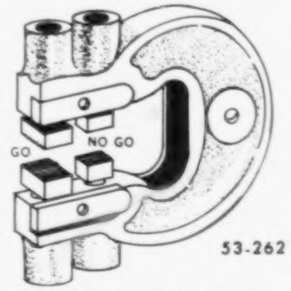


DOUBLE END LIMIT PLUG THREAD GAGE



GO RING GAGE

NO GO RING GAGE



ADJUSTABLE THREAD SNAP GAGE

Figure 5-39. Thread gages.

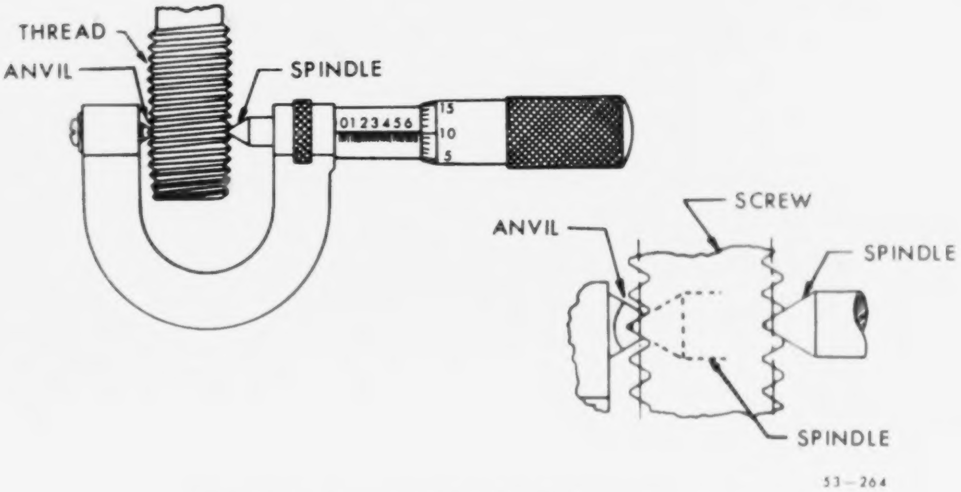


Figure 5-40. Measuring threads with a thread micrometer.

micrometer. The micrometer method is one of the most accurate methods for measuring pitch diameter.

Micrometer and wires. The pitch diameter of a thread can be accurately measured by an ordinary micrometer and three wires, as shown in figure 5-41.

The wire size which should be used to measure the pitch diameter depends upon the number of threads per inch. The most accurate results are obtained when you use the "best wire size." The best size is not always available, but you will obtain satisfactory results if you use wire diameters within a given range. Use a wire size as close as possible to the best wire size. You can use these formulas:

$$\text{Best wire size} = \frac{0.57735}{\text{number of threads per inch}}$$

$$\text{Smallest permissible size} = \frac{0.56}{\text{number of threads per inch}}$$

$$\text{Largest permissible size} = \frac{0.90}{\text{number of threads per inch}}$$

For example, the diameter of the best wire for measuring a thread having 10 threads per inch is 0.0577 inch, but any size between 0.056 inch and 0.090 inch could be used.

NOTE: The wires should be fairly hard and uniform in diameter. All three wires must be the same size. The shanks of drill bits can be used as substitutes for the wires.

The three-wire method does not measure the pitch diameter directly; it does this indirectly. A measurement taken over wires of a given diameter will be a specific dimension when the pitch diameter is correct. Use the following formulas to determine what the measurement should be.

$$\text{Measurement} = \text{major diameter of thread}$$

$$\frac{1.5155}{\text{number of threads per inch}} + (3\text{x wire diameter})$$

or

$$M = -\ MD\ \frac{1.5155}{\text{No. threads}} + (3W)$$

NOTE: The actual size of the wires should be used in the formula, not the calculated size. *Example*: What should the measurement over the wires be for a ¾-10-UNC thread if the diameter of the wire is 0.070 inch?

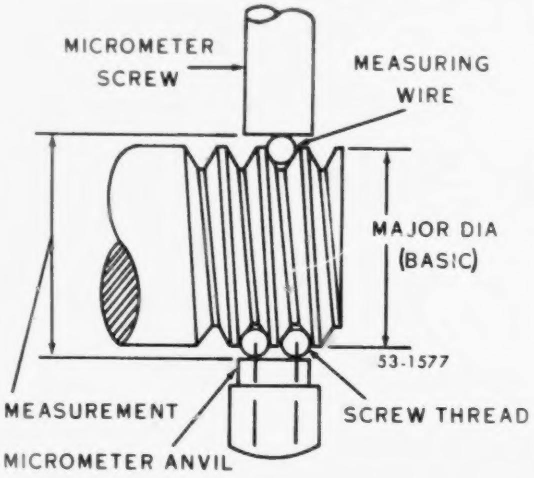


Figure 5-41. Measuring threads using three wires.

$$M = 0.750 - \frac{(1.5155)}{10} + (3 \times 0.070)$$

$$M = 0.750 - (0.15155) + (0.210)$$

$$M = 0.59845 + 0.210$$

$$M = 0.80845 \text{ inch}$$

Exercises (263):

1. Describe the thread gage and thread micrometer method of measuring threads.

2. Calculate the measurement over the wires for measuring a ¼-20-UNC thread when the wires measure 0.029 inch.

264. Explain the purpose of left-hand threads and the procedures for machining them.

Left-Hand Threads. Threads may be either right hand or left hand. A thread is a right-hand thread if it is advanced by turning it in a clockwise direction. A thread is a left-hand thread if it winds in a counterclockwise and receding direction when it is viewed axially. Most threads are right hand; therefore a thread is considered to be right hand unless the symbol LH is used on drawings, taps, dies, etc. Left-hand threads are used when the direction of motion required is opposite to that obtained with a right-hand thread. Examples are crossfeed screws or the left end of turnbuckles; or a situation in which a slippage between a part and a nut would tend to loosen a right-hand nut, such as on one end of a vehicle axle.

Left-hand threads are cut in approximately the same manner as right-hand threads except that the carriage moves toward the tailstock instead of away from it. Also, you swivel the compound rest to the left instead of the right to cut external left-hand threads, and to the right instead of the left to cut internal left-hand threads. Figure 5-42 shows the setup for machining external left-hand Unified threads. You grind the tools for left-hand threads with the relief and rake angles reversed from those on right-hand threading tools.

An undercut, or groove, is usually provided as a starting point for the left-hand threading tool. The undercut should be no narrower than the thread pitch and of a depth equal to, or slightly greater than, a single thread depth. The side nearest the thread should be chamfered.

Exercises (264):

1. Explain the purpose of left-hand threads.

2. How are tool bits for left-hand threads different from those for right-hand threads?

3. Explain how the work should be prepared prior to making the first cut for an external left-hand thread.

265. Analyze the characteristics of multiple lead threads, and explain the various procedures for machining them.

Multiple Threads. A multiple thread, as shown in figure 5-43, is a combination of two or more threads, parallel to each other, progressing around the surface into which they are cut. If a single thread is thought of as taking the form of a helix, that is, of a string or cord wrapped around a cylinder, a multiple thread may be thought of as several cords lying side by side and wrapped around a cylinder. There may be any number of threads, and they start at equally spaced intervals around a cylinder. Multiple threads are used in cases where rapid movement of the nut or other attached parts is desired and any weakening of the thread is to be avoided. A single thread having the same lead as a multiple thread would be very deep in comparison to the multiple thread.

The tool selected for cutting multiple threads has the same shpae as that of the thread to be cut and is similar to the tool used for cutting a single thread except that greater side clearance is necessary. The helix angle of the thread increases with an increase in the multiple thread. The general method for cutting multiple threads is about the same as for single screw threads, except that the lathe must be geared to the number of single threads per inch, or with reference to the lead of the thread, and not the

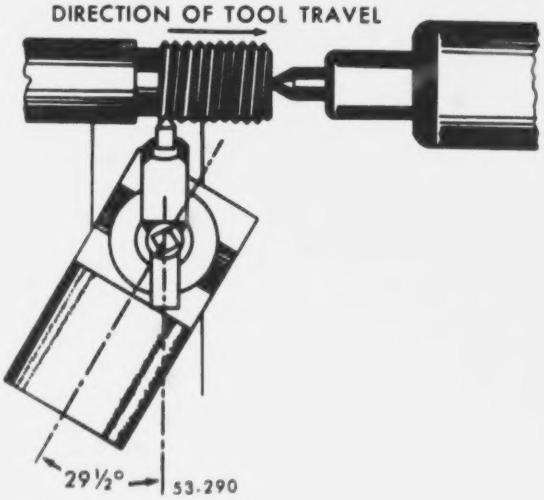


Figure 5-42. Setup for left-hand external threads.

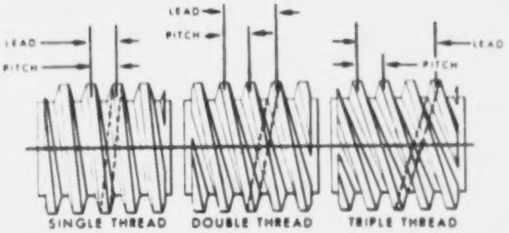


Figure 5-43. Comparison of single and multiple-lead threads.

pitch, as shown in figure 5-43. Provisions must also be made to obtain the correct spacing of the different thread grooves. This may be accomplished by using the thread-chasing dial, setting the compound parallel to the ways, using a multiple driving plate, or using the stud and box gear break up.

The use of the thread-chasing dial is the most desirable method for cutting 60° multiple threads. With each setting for depth of cut with the compound, successive cuts may be taken on each of the multiple threads so that the use of thread micrometers is made possible. To explore the possibility of using the thread-chasing dial, it is first necessary to find out if the lathe can be geared to cut a thread having a lead equal to that of one of the multiple threads. For example, if it is desired to cut 10 threads per inch, double threaded, it is necessary to divide the number of threads per inch by the multiple (in this case 10/2) to obtain the number of single threads per inch (in this case 5). The lathe is then geared for the number of single threads per inch. To use the thread-chasing dial on a specific machine, you should refer to instructions usually found attached to the lathe apron. If, for 5 threads per inch, you should engage the half nut at any numbered line on the dial, the same thread would be cut at positions 1 and 2 on the dial, as shown in figure 5-44. If the dial is then covered with the hand, leaving the part uncovered between those adjacent positions that cut the groove, positions 1 and 2 in figure 5-44, a check should be made to see if there is a point of engagement midway between positions 1 and 2 for the second thread. The second groove of a double thread lies midway of the flat surface between the grooves. There is a point of engagement in this case, position "b" in figure 5-44. For the same depth of cut, the half nut is engaged first at one of the "a" positions, then at "b" position so that alternate cuts bring both thread grooves down to size together. In the event that positions 1 and 2 would indicate the engagement place for groove of a triple thread, it would be necessary to have two positions of engagement, equally spaced, between positions 1 and 2 in order to cut the other grooves of the triple thread.

Cutting multiple threads by positioning the compound parallel to the ways should be limited to square and Acme external and internal threads, since that is the normal position of the compound for cutting those threads. The compound rest is set parallel to the ways of the lathe and the first thread is cut to the finished size. The compound and tool is then fed forward parallel to the thread axis a distance equal to the pitch of the thread and the next thread is cut, etc. Any desired multiple threads may be cut in this manner, provided that the lathe is geared to the lead of the multiple thread.

The multiple driving plate method of cutting multiple threads involves changing the position of the work between centers for each groove of the multiple thread. One method of accomplishing this is to cut the first thread groove in the conventional manner. Then the work is removed from between centers and replaced with the tail of the dog in another slot of the drive plate, as shown in figure 5-45. Two slots are necessary for a double thread, three slots for a triple thread, etc. The number of multiples that can be cut by this method depends upon the number of equally spaced slots in the drive plate. Special drive or index plates are obtainable, so that a wide range of multiples may be accurately cut by this method.

Another method of cutting multiple threads is to disengage either the stud or spindle gear from the gear train in the end of the lathe after cutting a thread groove. Then turn the work and spindle the required part of a revolution, and reengage the gears for cutting the next thread. If it is necessary to cut a double thread on a lathe having a 40-tooth gear on the spindle, the first thread groove is cut in the ordinary manner. Then one of

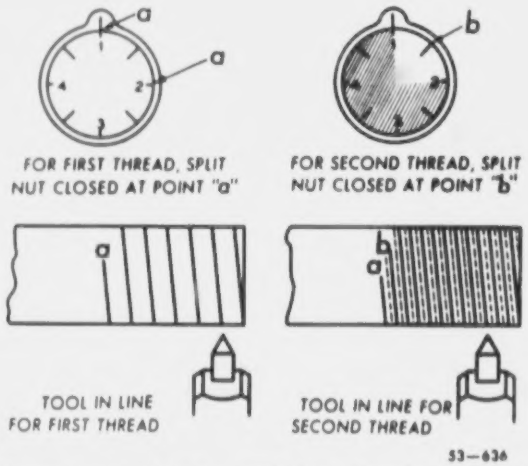

a
a
1
2
b
FOR FIRST THREAD, SPLIT NUT CLOSED AT POINT "a"
FOR SECOND THREAD, SPLIT NUT CLOSED AT POINT "b"
a
b
a
TOOL IN LINE FOR FIRST THREAD
TOOL IN LINE FOR SECOND THREAD
53—636

Figure 5-44. Cutting multiple threads using the thread-chasing dial.

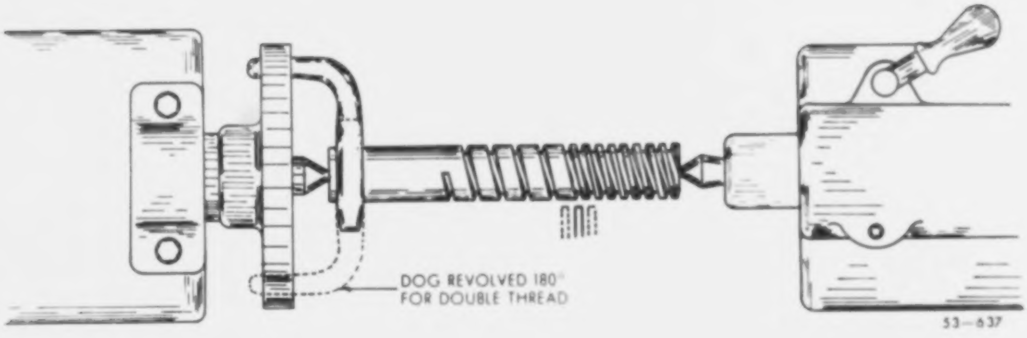


Figure 5-45. Use of slotted drive plate.

the teeth on the spindle gear that meshes with the next driven gear is marked and the mark is carried onto the driven gear, in this case the reversing gear. The tool diametrically opposite the marked spindle gear tooth (the 20th tooth of the 40-tooth gear) is marked also. The tooth next to the marked tooth should be counted as tooth number one. The gears may then be disengaged by placing the tumbler (reversing) gears in neutral position, the spindle is turned one-half revolution or 20 teeth on the spindle gear, and the gear train is reengaged. The stud gear may be indexed as well as the spindle gear. However, if the lathe does not have a 1 to 1 ratio between the spindle and stud gears, the stud gear instead of being turned as when geared for a 1 to 1 ratio would be given a proportional turn depending upon the ratio of the gearing. The method of indexing the stud or spindle gears is possible only when the number of teeth in the gear indexed is evenly divisible by the multiple desired. Some of the newer type lathes are equipped with a sliding sector gear that can be readily engaged or disengaged with the gear train by shifting a lever. Graduations on the end of the spindle show when to disengage and to reengage the sector gear for cutting various multiples.

Exercises (265):

1. Describe multiple lead threads and state why they are used.

2. How many threads per inch should a lathe be set up to cut if you want to machine a double-lead thread having 16 threads per inch?

3. Briefly describe the preferred method of cutting double lead threads.

4. Which method of cutting multiple lead threads is especially adapted to cutting Acme and square threads? Why?

266. Describe pipe thread characteristics and the procedures for cutting internal and external taper pipe threads with a lathe.

Pipe Threads. American Standard Taper Pipe Threads (NPT) are similar in form to the Unified thread; a common feature is that both have an included angle of 60°. Part of the threaded portion of the pipe is machined to a taper of ¾ inch per foot, and the threads are also machined at the same taper. The taper permits a tighter connection and seal between the mating threads than can be obtained with a straight thread. The nominal pipe size is the approximate inside diameter of the pipe. The actual outside diameter (the major diameter) can be found by measuring the pipe or by consulting a machinist publication.

The hole for tapered internal threads is straight bored to a diameter equal to, or slightly larger than, the minor diameter of the small end of the pipe. The taper length of both internal and external tapered pipe threads is equal to the length of the normal hand engagement. The thread length is equal to the length of the effective threads plus the length of the imperfect thread. The root of the imperfect threads will be the shape of the threading tool when the threads are cut on a lathe.

The most common setup for chasing tapered pipe threads on a pipe is shown in figure 5-46, but any suitable work setup can be used. Note, however, that the threading tool is positioned with the center gage aligned with the straight portion of the pipe and not with the taper. The tool setup is identical to the setup for machining Unified threads. The only difference is that the taper attachment is used when tapered pipe threads are machined.

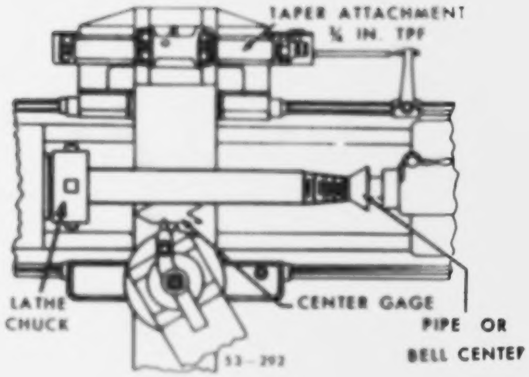


Figure 5-46. Pipe threading setup.

If the taper attachment requires the cross-slide to be clamped so that it cannot be moved, the threading tool must be withdrawn from the thread groove at the end of the threading cut by means of the compound rest. The spindle speed should be slow enough to insure adequate time to withdraw the tool to prevent damaging the work or the tool.

The pitch diameter is difficult to measure on tapered threads because of the taper; therefore the threads are normally machined to fit a taper thread gage or the mating part. The threaded parts should be assembled by hand to the distance equal to the normal engagement by hand, as given in machinists' publications such as the *Machinery's Handbook*.

Exercises (266):

1. Describe the features of taper pipe threads that are common to Unified threads.

2. How do taper pipe threads differ from Unified threads?

3. How is the threading tool positioned for cutting taper pipe threads?

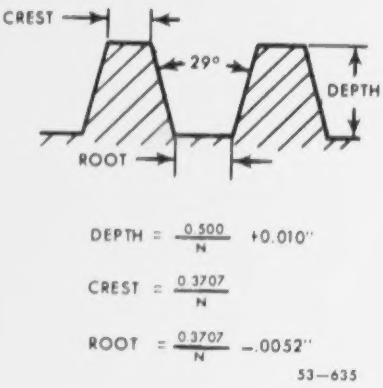
4. Describe the way in which a hole should be prepared for an internal taper pipe threading operation.

267. Explain the characteristics and methods of machining Acme and square threads, including the setup procedures.

Cutting Acme Threads. The American Standard Acme thread is a thread whose depth equals one-half the pitch plus an allowance for clearance, and the sides of the thread form an included angle of 29°, as shown in figure 5-47. The allowance for clearance for a single depth is 0.010 inch on threads of 10 per inch and less, and 0.005 inch on threads of more than 10 per inch. Formulas accompanying figure 5-47 for depth and root values are for threads having 0.010 inch clearance (1 to 10 threads per inch, inclusive). The pitch is equal to one divided by the number of threads per inch and is written P = 1/N. (For example, if a feed screw has eight threads per inch, the pitch is 1/N or 1/8 inch.) Since the depth of thread is 1/2P plus clearance, the pitch formula can be transformed into the depth formula as follows: Depth = (1/2N) + 0.010" = (0.500/N) + 0.010, as shown in figure 5-47.

The Acme thread is generally used on feed screws where it is rapidly replacing the less durable square thread. An Acme thread is slightly weaker but wears less rapidly than the square thread and may be cut with a die more rapidly than may a square thread. When an Acme thread is engaged by a half-nut, as in a lathe apron, engagement or disengagement is more readily made than with a square thread. An adjustable split nut may be used in connection with an Acme screw thread to compensate for wear and to eliminate backlash or lost motion because of its angular sides. The lathe setup for cutting the 29° thread is the same as that used for cutting a square thread.

The Acme thread is cut on the lathe with a tool which has been ground to fit the correct pitch of a 29° Acme thread gage. If the same tool is to be used for both roughing and finishing operations, it is ground to an included angle of 29°, a side clearance of 3° to 6° with respect to the thread helix, 0° side and back rake, and for a thread one pitch smaller than the thread being cut. After the thread is cut to the correct depth, the cutting edge of the roughing tool is sharpened and reset in the



$$\text{DEPTH} = \frac{0.500}{N} + 0.010''$$

$$\text{CREST} = \frac{0.3707}{N}$$

$$\text{ROOT} = \frac{0.3707}{N} - .0052''$$

Figure 5-47. Acme thread.

same position for finishing each side of the thread individually by feeding the compound rest (set parallel to the ways) to the right and left for the depths of cut. This method will prove satisfactory for most of the finer pitches and for threads requiring an ordinary degree of finish. For precision Acme threading,the roughing tool is used as previously described. The sides of the thread are individually finished by the use of two separate finishing tools, each having side rake with respect to the side being finished. Their cutting edges are individually set horizontally at center height and to the tool setting gage similar to the precision finishing operations used for American Standard threads and a square thread.

For the coarser pitches that are to be finished by individual finishing tools, the roughing tool may be ground with 0° side rake with respect to the helix angle of the thread in order to produce a free cutting action. During the roughing operation the depths of cut for large threads may be alternated between the cross-slide and compound rest in order to eliminate gouging that may occur when cutting with all three edges of a large Acme threading tool. Another method sometimes used for roughing out the thread is cutting the Acme thread to the proper depth by using a square tool having a width equal to the width of root of the Acme thread. This method is less desirable because the square tool is not as strong as the Acme tool and more time is required to complete the thread.

Cutting Square Threads. The principle uses of square threads are for jackscrews and for some machine tool feed screws. Square threads have been replaced to a large extent, however, by Acme threads, because of the difficulty encountered in machining the square threads.

A square thread is a thread whose sides are parallel, as shown in figure 5-48. The depth of the thread is equal to the width of space between the teeth. This space is, theoretically, equal to one-half of the pitch. It is necessary, in practice, however, to make the space in the nut a trifle wider than the thread to permit a sliding fit. The threads in the screws are made exactly according to the theoretical standard. The width of the point of the tool for cutting screws that require only an ordinary degree of finish and cut with one tool is, therefore, exactly one-half of the pitch. The width of the point of the tool for cutting taps which are to be used for threading nuts is slightly less than one-half the pitch. The width of an inside thread tool for threading nuts is slightly more than one-half the pitch.

Since square and Acme threads are usually cut with a relatively coarse pitch, a large helix angle is produced. Therefore, careful attention must be given to the clearance of the tool bit. In order to check accurately the amount of clearance necessary to prevent binding of the bit in the groove, a gage may be made, as shown in figure 5-49. To make such a gage you should scribe a line at 90° to one side of a small rectangular piece of sheet metal, and on it lay off a distance equal to the circumference of the thread to be cut at its minor diameter. At one end of this line and at right angles to it, lay off a distance equal to the pitch of the thread to be cut. Connect the ends of these two lines, and the angle of this third side is the angle of the required thread at its minor diameter. The sheet metal is then cut off along this last line, and the tool bit is gaged as illustrated in figure 5-49. The tool bit is considered correctly relieved when its side clears the gage from 3° to 6°.

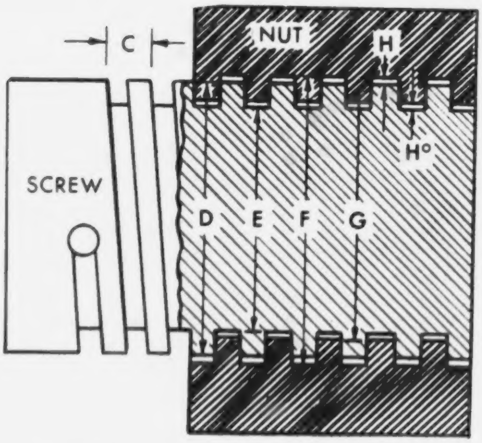

C
NUT
H
H°
SCREW
D
E
F
G
C—PITCH
D-MAJOR DIAMETER OF SCREW THREAD (BASIC SIZE)
E—MINOR DIAMETER OF SCREW THREAD (BASIC SIZE)
F—MAJOR DIAMETER OF NUT THREAD (D+CLEARANCE)
G—MINOR DIAMETER OF NUT THREAD (E+CLEARANCE)
H AND H°—CLEARANCE
53—294

Figure 5-48. Sectional view of square thread and nut.

For square external and internal threading, the compound rest is set parallel to the axis of the machine in order that material may easily be removed during finishing cuts. For precision thread cutting, a tool bit having 0° side rake with respect to the helix angle and ground from 0.002 inch to 0.008 inch undersize is used for the roughing cut while finishing is accomplished with tool bits having left and right rake. The front and back sides of the thread are finished by moving the compound rest parallel to the axis.

Exercises (267):

1. Describe an Acme thread.

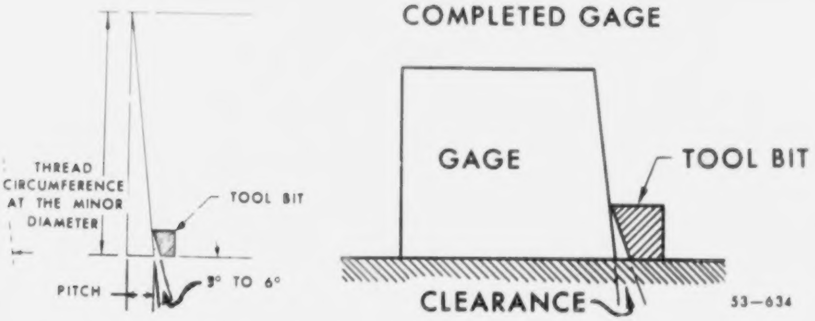


Figure 5-49. Gage for checking threading tool.

2. Explain how to prepare and set up a cutting tool to cut an Acme thread on the lathe.

3. Describe a square thread.

4. How does the threading tool bit design for cutting external square threads differ from the design for cutting internal square threads?

5. How is the tool fed into a square thread and how is the compound rest positioned?

268. Evaluate the use of end-gear changes to increase thread cutting ranges and to machine metric threads.

Change Gears for Threading. In preparing the lathe for thread cutting, the levers on the quick change gearbox are set to correspond to the number of threads per inch desired. Generally there are two or more levers on the box, along with a chart giving the position of these levers for the various threads to be cut. Change gears on older type lathes had to be set up in the gear train by hand to give required ratios between the spindle and lead screw to produce the desired leads. Change gears are those gears whose position and size may be changed to establish various ratios between the speed of the spindle and the speed of the lead screw. A set of change gears usually ranges in size from 16 teeth to 100 teeth by steps of 4 teeth, plus a few odd sizes for cutting certain odd thread pitches.

Metric change gears. Transposing gears are gears used to cut metric threads on a standard lathe. When metric threads are cut, the lead of the thread is given in millimeters, instead of in the number of threads per inch. To find change gears for cutting metric threads it is necessary to determine the number of threads per inch corresponding to the given lead in millimeters. As an example, suppose a thread is to be cut with a pitch of 2 millimeters on a lathe with a lead screw of 6 threads per inch. There are 25.4 millimeters per inch. The number of threads per inch is 25.4 divided by 2. Place the lead screw constant in the numerator and the desired number of threads in the denominator:

$$\frac{6}{\frac{25.4}{2}} = 6 \div \frac{25.4}{2} = \frac{6 \times 2}{25.4} = \frac{12}{25.4} = \text{ratio to obtain desired lead}$$

This then represents the ratio between the change gears necessary to cut the metric thread. The 25.4 shown in the denominator must be converted into a whole number and the smallest whole number by which it can be multiplied to get a whole number is 5. Thus 25.4 × 5 = 127. One gear with 127 teeth is always required to cut metric threads with a lathe, and the other gear required in this example has 60 teeth, as shown below:

$$\frac{12}{25.4} \times \frac{5}{5} = \frac{60}{127} = \frac{\text{driving gear}}{\text{driven gear}}$$

Increasing threading ranges. To increase the range of thread leads that can be cut on a lathe with a quick change gearbox, the following formula for calculating gears may be used:

$$\frac{A \times B}{C} = X$$

Where
A = number of teeth on the spindle or spindle stud gear.
B = number of threads per inch to be cut.
C = number nearest to B on the quick change gearbox that will make X an even number.
X = number of teeth on the spindle replacement gear.

As an example, assume it is desired to cut 27 threads per inch and the gear on the spindle or spindle stud has 32 teeth. By trial it is found that 24 threads per inch on the quick change box is the nearest to 27 which will make X come out to an even number.

$$\frac{A\ X\ B}{C} = \times\ \frac{32 \times 27}{24} = 36$$

The 32-tooth gear on the spindle stud is replaced by the 36-tooth gear. Then with the lathe set to cut 24 threads per inch, 27 threads per inch will be cut instead. NOTE: Always replace the original spindle gear after cutting a thread not included in the quick change gearbox, because the lathe will not cut the threads listed until the original gear is replaced.

Exercises (268):

1. Before you can determine the proper lathe setup to cut a metric thread, what must you do with the pitch designation of the metric thread?

2. What gears should you use on a lathe on which the lead screw has 6 threads per inch to cut a metric thread with a pitch 4 millimeters?

3. Explain how to determine the number of teeth on the spindle replacement gear when you must cut a thread lead that is not available on the lathe thread chart.

269. Describe the methods of tap and die threading in a lathe, and list the safety precautions involved.

Tap and Die Threading in the Lathe. Threads that do not require the high degree of accuracy and finish obtained by chasing the threads can be cut by taps and dies. These methods are faster than chasing in the lathe.

Tapping threads in a lathe. Tapping can be done in the lathe by power or by hand. Regardless of the method, the hole must be drilled with the proper size of tap drill and must be chamfered. The shank end of the tap is supported by the tailstock center. A slight pressure is maintained against the tap to keep its center hole on the center and to help the cutting teeth of the tap engage the work.

The work rotates when you are tapping by power. Use a very slow spindle speed (10 rpm to 30 rpm) and plenty of lubricant for power tapping. The tap is prevented from rotating by a tap wrench; the handle of the wrench should contact the compound rest. The use of power is not recommended for taps under ½ inch diameter or in tapping steel. Be sure that the tap wrench handle contacts the compound rest before you engage the spindle, and keep your fingers away from the tap wrench. Do not attempt to start the tap in the hole with the work revolving. Keep the center snug in the center hole to prevent the tap from becoming misaligned and then breaking.

The setup for hand tapping in a lathe is similar to the power tapping setup and to tapping in a drill press. Set the lathe for a low spindle speed with the motor turned off. This helps to prevent the spindle from turning because of the cutting pressure. Lathe chucks can be positioned so that one of the chuck jaws contacts the compound rest to prevent the chuck from turning when large taps are used.

Whenever it is possible, work held in a collet should be set up and locked with a lathe dog. The lathe dog prevents the work from slipping in the collet. This method of securing the work can be used only with draw-bar collet attachments that permit the drive plate to be mounted while the collet attachment is being used.

An open-end wrench can be used in place of the tap wrench if the tap wrench is too long to turn. The center prevents the tap from being pulled "off center." The center does not need to support the tap after sufficient threads have been cut to insure proper alignment.

NOTE: Back off the tap frequently to break the chip, just as in tapping on a drill press, and use a lubricant.

Die threading in a lathe. Die threading in a lathe is very similar to tapping in a lathe, except that the die is aligned perpendicular to the work axis by pressure exerted against the back surface of the die. The pressure can be applied by means of a drill pad as illustrated; by the front surface of the tailstock spindle; or, for very small dies, by the front surfaces of the drill chuck jaws. The jaws should be closed enough to insure that they are contacting the die, and not the diestock. Die threading can be done by power or by hand, using the same procedures as in tapping in a lathe. If the diestock handles do not clear the ways of the lathe, when you are threading by hand, remove the handles from the diestock. Install one of the handles in the diestock and rotate the diestock with the handle as far as possible. Remove the handle and install it in the opposite end of the diestock. Again, rotate the diestock as far as possible. Continue alternating the handle from end to end and turning the diestock until the threads are the length you want. Power can be used to remove the die from the threaded work by reversing the direction of the spindle rotation. If the lathe spindle is not reversible, place it in neutral and rotate the spindle by hand to remove the die from the work. It is difficult to cut very coarse threads with a die because of the great amount of force needed to turn the die. It is advisable to first rough out the threads with the die in the full open position; then perform a finish cut with the die closed down. Use a lubricant during both the cutting and removal operations.

Another type of die threading that is commonly used in the Air Force is with a radial die set, as depicted in figure 5-50. This type of die (commonly called a geometric die) is held in the tailstock spindle and the tailstock must be slid along the way as the die cuts the threads. When the correct length of threads has been cut, a slight backward pull on the tailstock will cause the die to spring open. Then the die can be pulled off the threads without having to screw them out.

The inserted die teeth, called chasers, must be inserted in the correct slot and in the proper order. If they are not, the die will not produce a usable thread. Most geometric sets have a rough/finish level. Set the lever for "R" and cut the desired thread; then set the lever to "F" and run the die over the threads again to produce a very accurate and smooth thread. The chasers are produced for most thread sizes up to the capacity of the particular set used (the chasers should never be interchanged between die sets). There is an adjustment on the die head that allows a thread to be cut slightly smaller or larger than its standard size. Cutting oil should always be used when cutting steel with this type of die. The work should be chamfered to allow the die teeth to start easily. NOTE: Never allow the die to be bumped onto the work. It should be started carefully to prevent the teeth from being broken.

Exercises (269):

1. What is the recommended rpm range for tapping by power?

2. How should the tap be secured from turning when you are tapping threads by power in the lathe?

3. How is a die aligned properly when used on a lathe?

4. Describe the procedure for cutting a thread with a radial die set.

5-5. Special Lathe Operations

There are several lathe operations that involve the use of special lathe attachments or that are not used as often as some of those we have discussed already. One exception is the knurling process. It is a very commonly used process but we have included it in this section because of the special tool that is used to accomplish it. Along with knurling, we will also discuss the tool-post grinder, spring winding, and the use of several lathe attachments.

270. Identify the types, patterns, and uses of knurling tools, and describe the knurling process.

Knurling. Knurling is the process of rolling or squeezing impressions into the work by means of hardened steel rollers that have teeth milled in their faces. Knurling provides a gripping surface on the work; it is used also for decoration.

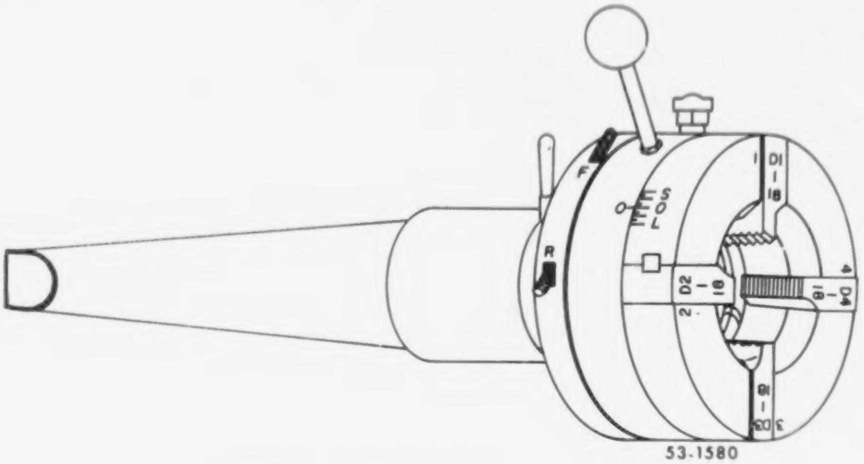


Figure 5-50. Radial diehead.

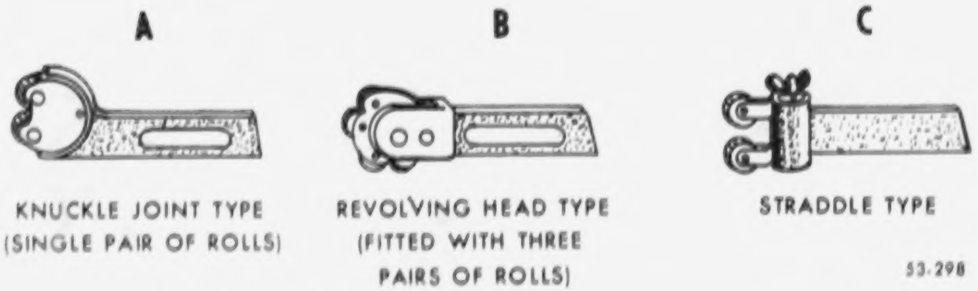

A
B
C
KNUCKLE JOINT TYPE (SINGLE PAIR OF ROLLS)
REVOLVING HEAD TYPE (FITTED WITH THREE PAIRS OF ROLLS)
STRADDLE TYPE
53-298

Figure 5-51. Types of knurling tools.

Knurling increases the diameter of the work slightly.

Knurling tools. The three common types of knurling tools are the knuckle joint, shown in figure 5-51,A; the revolving head, shown in figure 5-51,B; and the straddle, shown in figure 5-51,C. The revolving head type has three sets of rolls, while the knuckle and straddle types each have one set of rolls. NOTE: The straddle-type knurling tool is used primarily to knurl small diameter work. The work revolves between the two rolls and is not distorted because the pressure of one roll counteracts the other.

There are two patterns of knurls, diamond and straight line, and three pitches, fine, medium, and coarse, in each pattern, as shown in figure 5-52. The diamond is the most common pattern, and the medium is the most common pitch. The coarse pitch is used for large diameter work and the fine pitch for small diameter work.

Knurling setup. The knurling tool is positioned with the faces of the rolls parallel to the surface of the work and with the upper and lower rolls equally spaced above and below the work axis. The spindle speed should be approximately half the rough turning speed, but do not exceed the highest speed permitted for shifting the feed reverse mechanism on the lathe. The feed should be between 0.015 inch and 0.025 inch. The center holes should be as large as practical so as to provide as much bearing surface as possible to absorb the pressure of the knurling tool. Work mounted in a chuck should also be supported at the tailstock end with a center to prevent damaging the work or destroying the accuracy of the chuck.

The knurling operation. You perform the knurling operation in two ways: (1) for ordinary knurling and (2) for knurling between layout lines.

Ordinary knurling is performed in the following manner. Set up the work and lay out the length of the portion to be knurled. Set up the knurling tool. Set the lathe for the correct spindle speed and the correct feed. Check the knurling tool to insure that the rolls revolve freely and that the revolving head is free to move also. Oil the rolls and the pins on which the rolls revolve by flooding the knurling toolhead with oil. Apply oil to the work and the knurling tool generously during the knurling operation. Apply oil to the surface of the work opposite the knurling tool with an oilcan (keep the spout well away from the knurling tool rolls) or with a brush. CAUTION: Keep rags, brushes, and your fingers away from the knurling tool during the knurling operation.

Position the carriage so that a third to a half of the face of the rolls extends beyond the end of the work. This eliminates part of the pressure required to start the knurl impression. Force the knurling rolls into contact with the work. Engage the spindle clutch. Check the knurl to see if the rolls have tracked properly, as shown in figure 5-53, by disengaging the clutch after the work has revolved three or four times and by backing the knurling tool away from the work by means of the cross-slide. If the rolls have "double tracked," as shown in figure 5-53, move the carriage to a new location and repeat the operation. If the knurl is correctly formed, engage the spindle clutch and the carriage feed. Move the knurling rolls into contact with the knurled impressions. (The rolls will align themselves with the impressions.) Allow the tool to knurl to within 1/32 inches of the layout line.

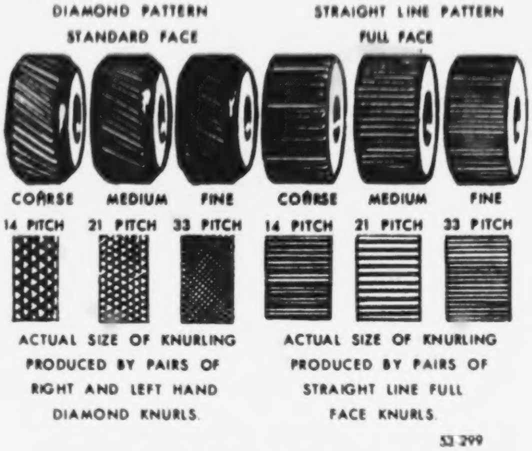

DIAMOND PATTERN
STANDARD FACE
STRAIGHT LINE PATTERN
FULL FACE
COARSE
MEDIUM
FINE
COARSE
MEDIUM
FINE
14 PITCH
21 PITCH
33 PITCH
14 PITCH
21 PITCH
33 PITCH
ACTUAL SIZE OF KNURLING PRODUCED BY PAIRS OF RIGHT AND LEFT HAND DIAMOND KNURLS.
ACTUAL SIZE OF KNURLING PRODUCED BY PAIRS OF STRAIGHT LINE FULL FACE KNURLS.
53-299

Figure 5-52. Knurl patterns.

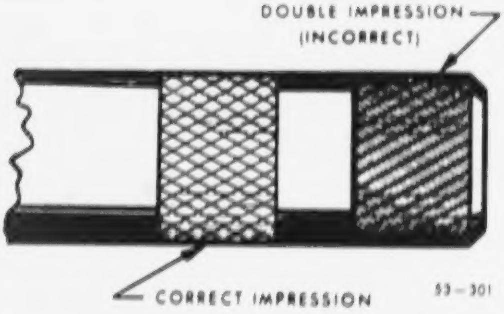


Figure 5-53. Knurled impressions.

Disengage the carriage feed and, with the work revolving, feed the carriage by hand to extend the knurl to the layout line. Force the knurling tool slightly deeper into the work, reverse the direction of the carriage feed, and engage the carriage feed. Allow the knurling tool to feed to the right until approximately half of the rolls extend beyond the end of the work. Never allow the knurling tool to feed entirely off the end of the work. Repeat the knurling operation until the diamond-shaped impressions converge to a point. If additional passes are made after the pattern has completely formed, the points may be stripped away from the surface. Move the knurling tool away from the work and, with the work revolving, clean the knurled work surface with a fine brush. Remove any burrs, which may have formed at the end of the work due to the knurling pressure, by machining or by filing.

You use a slightly different method to start the knurling operation when you knurl between layout lines. You can perform this operation in the following manner. Set up the work, lathe, and knurling tool as usual. Swing the compound rest to the right 5° to reduce the starting pressure. Position the knurling tool slightly to the left of the right-hand layout line, and start the knurl by forcing the corner of the roll into the work surface. Move the carriage by hand and, if the knurl is tracking properly, extend the knurl to the right-hand layout line. Move the knurling tool clear of the work and position it parallel to the work surface by swinging the compound rest back to the left 5°. Continue the knurling operation in the same manner as in knurling to the end of the shaft.

Regardless of the method of knurling that you use, do not allow the work to rotate if the knurling tool is contacting it and the carriage travel is stopped, or rings will form, as shown in figure 5-54. Do not stop the work without relieving the knurling tool pressure. The pressure may distort or spring the work. Remember to keep the knurling tool and the work well oiled throughout the operation. Check the adjustment of the tailstock center frequently. The pressure of the knurling operation may cause the centers to loosen slightly.

Exercises (270):

1. What is the knurling process used for?

2. State the types of knurling tools and describe the positioning of the rollers in each.

3. What patterns and pitches are available on knurling tools?

4. What should be the most important consideration when mounting work for knurling?

5. Describe the procedure to follow if the knurling rollers double track at the start of a knurling operation.

6. Describe the procedure for starting a knurl between layout lines.

271. Describe the toolpost grinder operation—including setup techniques, wheel dressing, and safety precautions.

Toolpost Grinder. The toolpost grinder is a portable grinding machine that can be mounted on the compound rest of a lathe in place of the toolpost, and it can be used to machine work that is too hard to cut by ordinary means or to machine work that requires a very fine finish. Figure 5-55 shows a typical toolpost grinder. The grinder must be set on center, as shown in figure 5-56. The centering holes located on the spindle shaft are used for this purpose. The grinding wheel takes the place of a lathe tool bit. It can perform most of the operations that a tool bit is

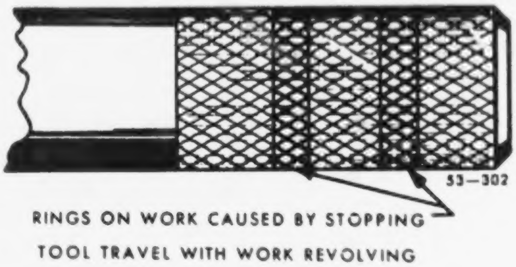

53—302
RINGS ON WORK CAUSED BY STOPPING
TOOL TRAVEL WITH WORK REVOLVING

Figure 5-54. Rings on a knurled surface.

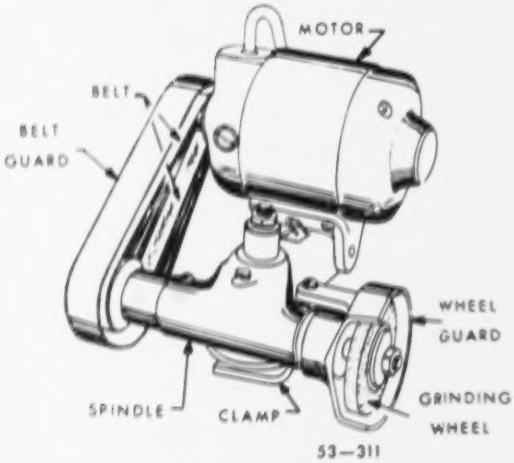


Figure 5-55. Toolpost grinder.

capable of performing. Cylindrical surfaces, tapered surfaces, and internal surfaces can be ground with the toolpost grinder. Very small grinding wheels are mounted on tapered shafts known as quills in order to grind internal surfaces.

The grinding wheel speed is changed by using various sizes of pulleys on the motor and spindle shafts. An instruction plate on the grinder gives both the diameter of the pulleys required to obtain a given speed and the maximum safe speed for grinding wheels of various diameters. (CAUTION: Grinding wheels are safe for operation at a speed *just* above the highest recommended speed. A higher than recommended speed will result in the increase in centrifugal force which may cause the wheel to explode. This is one reason that they offer protection in case you select a higher speed by mistake. Avoid such a mistake by careful checking.)

Wheel guards are furnished with the toolpost grinder. Always check the pulley combinations given on the instruction plate of the grinder when you mount a wheel. Be sure that the combination is not reversed, because this may cause the wheel to run at a speed far in excess of that recommended. During all grinding operations wear goggles to protect your eyes from flying abrasive material.

The grinding wheel must be dressed and trued. Use a diamond wheel dresser to dress and true the wheel. The dresser is held in a holder that is clamped to the drive plate. Set the point of the diamond at center height and at a 10° to 15° angle in the direction of the grinding wheel rotation, as shown in figure 5-57. The 10° to 15° angle prevents the diamond from gouging the wheel. Be sure the lathe motor is turned *off* and then lock the lathe spindle by placing the spindle speed control lever in the low RPM position. (NOTE: The lathe spindle does not revolve when you are dressing the grinding wheel. And don't forget to remove the diamond dresser holder as soon as the dressing operation is completed.) Bring the grinding wheel into contact with the diamond by carefully feeding the cross-slide in by hand. Move the wheel clear of the diamond and make a cut by means of the cross-slide. The maximum depth of cut is 0.002 inch. Move the wheel slowly by hand back and forth over the point of the diamond. Move the carriage if the face of the wheel is parallel to the ways of the lathe, or move the compound rest if the face of the wheel is at an angle. Make the final depth of cut of 0.0005 inch with a slow, even feed to obtain a good wheel finish.

Rotate the work at a fairly low speed during the grinding operation. The recommended surface speed is 60 to 100 feet per minute (fpm). The depth of cut depends upon the hardness of the work, the type of grinding wheel, and the desired finish. Avoid taking grinding cuts deeper than 0.002 inch until you gain experience. Use a fairly low rate of feed. You will soon be able to judge whether the feed should be increased or decreased. NOTE: Never stop the rotation of the work or the grinding wheel while they are in contact with each other.

Toolpost grinders are often used to refinish damaged lathe centers. If the lathe is to be used for turning work between centers in the near future, grind the tailstock center first, then the headstock center. Leave the headstock center in position for the turning operation. This method provides the greatest degree of accuracy. If the headstock spindle must be removed in order to perform other operations, a mark placed on the headstock spindle sleeve and center will enable you to install them in the same position they were in when the center was ground and thus insure the greatest degree of accuracy for future operations involving turning work between centers.

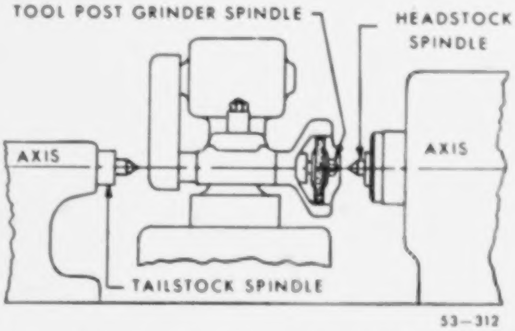


Figure 5-56. Mounting the grinder at center height.

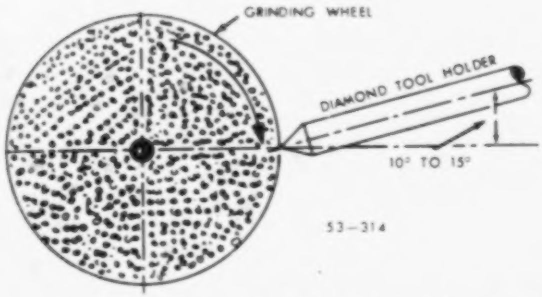


Figure 5-57. Position of the diamond dresser.

Exercises (271):

1. Describe the process of setting the toolpost grinder at center height.
2. How are grinding wheels for internal grinding mounted?
3. What kind of accident might be avoided if the recommended grinding wheel RPM is checked prior to mounting?
4. Describe the procedure for setting up the diamond wheel dresser preparatory to a toolpost grinding operation.
5. What should you do before you stop the work to check the ground surface during a grinding operation?

272. State the characteristics of tension and compression springs, and analyze the materials and procedures used in the spring winding process.

Spring Winding. When a small number of springs of the helical or coil form are needed in connection with repair work, it is common practice to wind them on the lathe. When springs are manufactured in large quantities, special spring winding machines are used. Single coil springs are made on a lathe, using the simple setup shown in figure 5-58.

Coil springs may be of the tension or the compression types (figure 5-59). A tension spring, figure 59, A, is one in which the coils lie one against the other as in a screen door spring. When tension or pull is exerted on the spring, the coils are spread apart and the tendency of the spring is to pull back to its original form. A compression spring, figure 5-59,B, is one in which the coils are wound a definite distance apart with a fixed space between them. The valve springs of automobiles are an example of compression springs. When force is exerted on the spring it is compressed and the coils have a tendency to push or spring back to their original form.

Spring wire material. Different grades and types of spring wire material are used for winding springs because of the different requirements, such as resistance to fatigue, corrosion, temperatures, etc. Steel containing about 1 percent of carbon and comparatively free from phosphorus and sulfur, known as spring steel, is ordinarily used for springs. For small springs, music wire is used to a great extent and is the best material obtainable for this purpose. Music wire ranges from 0.004 inch to 0.146 inch in diameter. The carbon content of music wire varies from 0.70 percent to 1.00 percent and manganese from 0.25 percent to 0.40 percent. Music wire is more expensive than ordinary spring wire, but can be subjected to higher stresses. Phosphorus bronze wire may be used if steel wire would corrode rapidly. It usually contains about 5 percent tin, a trace of phosphorus to prevent brittleness, and the remainder copper. Brass wire is inferior to phosphorus bronze wire but may be used when the cost of material is an important factor. Monel and inconel have excellent corrosion-resistant properties and will withstand abnormally high temperatures.

Fabrication of springs. You can wind springs on the lathe on mandrels of the proper size, using spring wire of the required material and diameter. Pass the wire between wood or brass blocks or through a spring wire holder. Fasten the end of the wire between a chuck jaw and the mandrel. The other end of the mandrel is

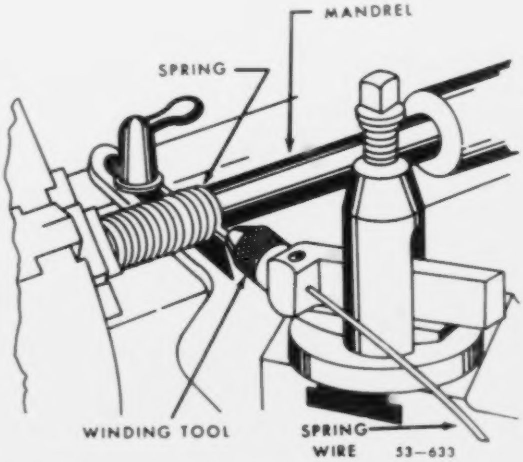


Figure 5-58. Winding springs in a lathe.

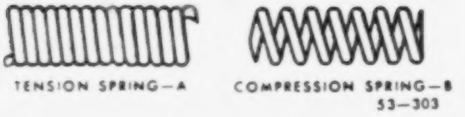


Figure 5-59. Coil springs.

supported by the tailstock center. Mandrels having a diameter greater than ⅜ inch are held in a lathe chuck, while mandrels less than ⅜ inch in diameter may be held in a drill chuck. Clamp the wire between the blocks or in the wire holder just tight enough to keep it from slipping and still hold a uniform tension on the wire so that it is wound tightly against the mandrel. When the spring is wound to the desired length, relieve the tension, clip the wire off, and remove the spring from the mandrel.

Springs are wound on the lathe by causing the lathe carriage and the wire holder to move a distance equal to the lead of the required spring for each revolution of the spindle. The speed at which the lathe lead screw turns in relation to the speed of the lathe spindle determines the distance the carriage and wire holder will advance when the half nut is closed over the lathe lead screw. The lathe is geared to the pitch or lead of the spring to be wound in the same way that you would gear it to cut a thread of the same pitch.

Exercises (272):

1. Describe the characteristics of both tension and compression springs.
2. What is the approximate composition of the most commonly used metal for making springs?
3. What kind of wire should be used for making a spring that will be used in a corrosive environment?
4. Describe the way in which the spring wire is fed onto the mandrel.

273. Explain the purpose, characteristics and operation of the center rest, the follower rest, and the micrometer carriage stop.

Center Rest. The center rest consists of a frame and three adjustable jaws, figure 5-60, which support the work at some point along the axis of the work. One purpose of the center rest is to prevent springing or deflection of slender flexible work. Another is to furnish auxiliary support to permit taking a heavier cut. Still another is to support work for drilling, boring, or internal threading. An overarm is provided so that work may be removed and replaced without disturbing the jaw adjustment. In that way we can machine duplicate pieces.

The center rest may be used on work held in a lathe chuck or on work held on the headstock center. It is first necessary to machine a concentric bearing surface on the work, at the place where the jaws are to be applied. After the work is mounted and the center rest is clamped in place to the ways of the lathe, the jaws are carefully adjusted to the surface of the work. A slight clearance must be left between the jaws and the work. The clearance allows for lubrication in order to prevent scoring of the work and of the center rest jaws. When you are adjusting the center rest jaws to ground work, copper shims may be used between the jaws and work to prevent marring the finished surface of the work.

Many times the work that must be supported by the center rest is of an irregular nature, hexagonal and square stock, or long and slender work that is too small for the center rest jaws. The cathead, figure 5-61, is used to provide a bearing surface on this type of work. It consists of a concentric bearing surface and a series of adjustable set screws. When you use the cathead, the bearing surface is adjusted to work by means of the adjusting screws until it runs true. A dial test indicator may be used to check the trueness of the bearing surface as the work is revolved by hand. The center rest jaws are then adjusted to the bearing surface of the cathead.

Follower Rest. Long shafts that are likely to be sprung out of alignment by the thrust of the cutting tool often require the support of a follower rest, figure 5-62. A follower rest mounts on the

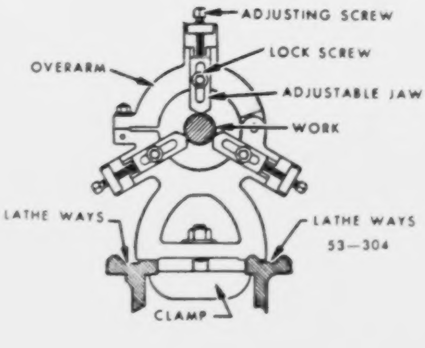


Figure 5-60. Center rest.

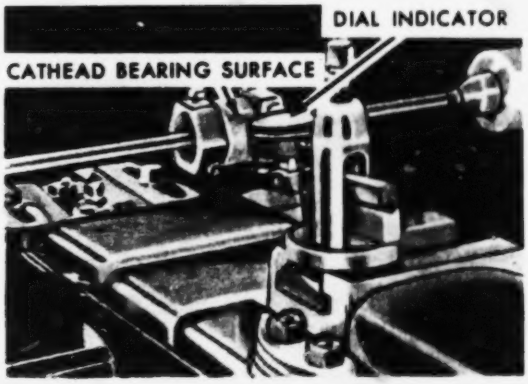


Figure 5-61. Cathead.

carriage of the lathe and hence moves with the tool, backing up the work opposite the point of tool thrust. Follower rests have two adjustable supporting jaws. One holds the work down to prevent the tendency to climb on the tool. The other is behind the work to counter the thrust of the tool.

The cutting tool may be set to precede the jaws of the follower rest for the first cut and then set to follow the jaws for the second cut. This eliminates the necessity of adjusting the jaws for each cut. The jaw adjustments are made the same as the center rest.

A follower rest is useful in turning and threading long work of small diameter. Since the diameter of the work does not change, one adjustment of the jaws is sufficient. When it is used in a threading operation, it is necessary to remove any burrs by filing. Burrs which may bear against the follower rest jaws may cause the work to revolve out of alignment.

Micrometer Carriage Stop. The micrometer carriage stop, shown in figure 5-63, is used to accurately position the lathe carriage. Move the carriage so that the cutting tool is approximately positioned, and clamp the micrometer carriage stop to the ways of the lathe, with the spindle in contact with the carriage. The spindle of the micrometer carriage stop can be extended or retracted by means of the knurled adjusting collar; the graduations on the collar (which indicate movement in thousandths of an inch) make it possible for you to accurately set the spindle. Next bring the carriage into contact with the micrometer spindle again. The carriage can be accurately positioned within 0.001 of an inch, which is very useful when you are facing to length or machining shoulders to an exact length. After making a cut, bring the tool back to the start of the cut by means of the carriage stop. This feature is very useful when you must remove a tool, such as the internal recessing tool, from the hole to take measurements and then reposition it to take additional cuts. NOTE: Always bring the carriage into contact with the stop by hand. Use power feed to bring the carriage within 1/32 inch of the stop, and move the carriage by hand the remaining distance.

Hang in there! We have one more section to go in this volume. It concerns lathe installation and maintenance. But first – you guessed it! Here are a few more questions to test your reading skills.

Exercises (273):

1. For what purpose is the center rest used?

2. What should you do to protect the work surface when using the center rest on ground work?

3. How can you use the center rest on square stock without machining a bearing surface on it?

4. Explain how the follower rest is different from the center rest.

5. A cutting tool can be positioned within what part of an inch when the micrometer carriage stop is used?

5-6. Lathe Maintenance

Knowing how to use a lathe is important, but it is just as important to know how to install and take care of one. A lathe is an extremely expensive piece of equipment and must be

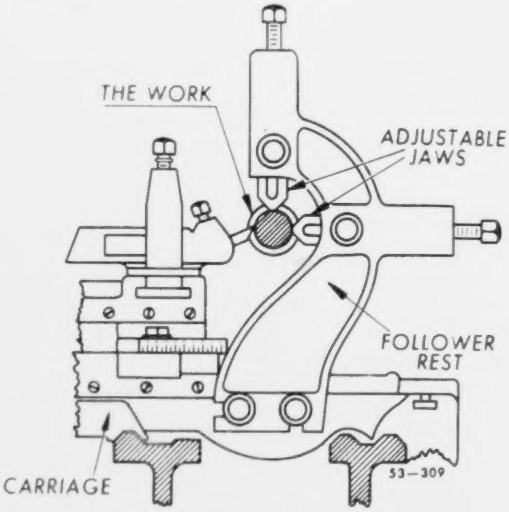


Figure 5-62. Follower rest.

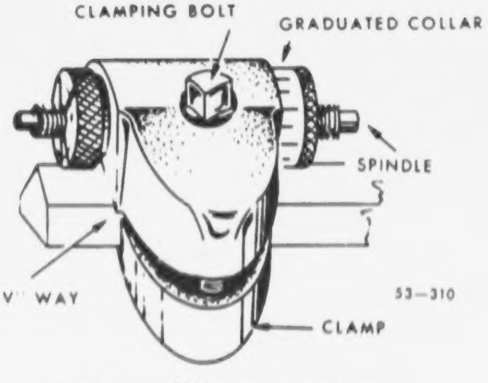


Figure 5-63. Micrometer carriage

properly taken care of if it is to perform efficiently. This section is designed to help you understand how to care for a lathe.

274. List the factors to consider when installing a lathe in a machine shop.

Installation. Installation includes (1) handling of the lathe when it is received in the shop, (2) installing, and (3) leveling.

Handling. The various models of lathes require different methods of lifting. A heavy rope is better than chains or a cable for lifting the machine because it is less likely to damage the metal surfaces. If you have to use chains or a cable, pad the machine surfaces heavily to prevent damage. Leave the skids or pallet on which the lathe is mounted under the machine until it is placed in a permanent position.

Installing. Before a lathe is permanently placed in a shop, you should make a space check to insure that there is ample space around the machine so that the operator is not crowded. A floor plan or a dimensional drawing with the manufacturer's recommendations is usually furnished with the machine. Allow ample space over and above the exact size of the machine. The floor should be fairly level, with a solid foundation. In some cases it may be necessary to reinforce the floor, since vibration caused by a weak floor would cause the machine to go out of level.

Leveling. The lathe must be leveled and bolted securely to the floor to prevent distortion of the lathe bed and ways. A lathe can be leveled by driving wedges of hard wood, shingle, or shim stock between the base of the machine and the floor. Use a precision level to check the levelness of the lathe bed. A carpenter's level or a combination square level is not sensitive enough. Check the bed by placing the level crosswise on the ways at the headstock and tailstock ends. Then place the level lengthwise on the ways. It is important to check the levelness of the bed in both directions.

Exercises (274):

1. What three operations are included in lathe installation procedures?

2. If you must use chains to lift a lathe, how should you protect the metal surfaces?

3. Once you find a suitable spot for a lathe and it has been set in position, what else must be done before it can be operated?

275. Specify the lubrication and maintenance requirements for lathes, including the various adjustments required to correct malfunctions.

Lathe Maintenance. Lathe maintenance is important and must not be neglected. Good maintenance makes it possible for you to get the best results in lathe operations, and it lenghtens the life of the machine. A lathe that is improperly maintained soon wears out. To keep the lathe in the best operating condition, we must make frequent inspections and various adjustments. A periodic check should be made of such things as levelness, spindle bearing condition, clutches, gibs, crossfeed and lead screws, gearing, and lubrication. Adjustments should be made only when it is necessary. Since the different makes of lathes vary in their construction, it is always best to follow the manufacturer's directions on making these adjustments.

Gib adjustments. Gibs may be either tapered or flat metal bars for taking up wear between bearing surfaces, such as the dovetailed surfaces of the cross-slide, compound rest, or carriage. Gibs are provided with thrust screws by which the necessary adjustments are made. In making gib adjustments, first loosen the lockscrew. Next tighten the gib screw until a smooth snug fit is obtained. Then lock the adjustment. If gibs are adjusted too tightly, binding will result. Gibs on the compound slide should be fairly tight when the compound is not being used for cutting angles.

Headstock spindle. The spindle bearings of the newer type are generally of the nonfriction or taper roller bearing type. They are properly adjusted at the factory and need not be adjusted for long periods of time. When spindle bearing adjustments are necessary, they may be adjusted by means of a thrust nut. The adjusting nut is generally located on the rear end of the spindle, outside the headstock to allow for easy adjustment. When you make spindle bearing adjustments, place the headstock gearing in neutral so that the spindle revolves freely. Remove the back gearing guard and release the locknut or set screws that hold the thrust nut in place. With a spanner wrench provided for that purpose, turn the thrust nut clockwise until no end play is detected and the spindle can still be rotated freely by hand. A drive plate should be placed on the spindle so that the spindle may readily be rotated by hand. Adjustments on other types of bearings are essentially the same. CAUTION: Before making any spindle adjustments, make certain the trouble does not lie elsewhere. Check and make other adjustments first.

Driving clutches. The types of clutches incorporated by various lathe manufacturers may vary. Consequently the method of clutch adjustment is not the same. The more expensive precision lathes generally have the friction type of clutch similar to that of an automobile. To make adjustments of the friction-type clutch, remove the clutch guardplate, pull back the adjusting pin, and rotate the adjusting yoke or ring to the right or clockwise until the pin slips into the next hole or notch. Proper adjustment is made when the clutch level snaps in and out of engagement.

Apron feed clutches. Apron feed clutches vary somewhat in design. They may consist of two friction cones or two serrated plates held together under cam pressure and released under spring tension. A thrust screw in the clutch shaft makes whatever adjustment is necessary. To adjust, turn the thrust screw clockwise until the clutch level snaps in and out of engagement.

Lead screw. The lead screw is adjusted for end play by removing the cap from the end of the screw and tightening the thrust collar. Adjustment for end play can be checked by engaging the half nut and moving the carriage, by hand, back and forth along the ways.

End gearing. To make adjustments on end gearing, remove the guard and loosen the stud nuts of the gear quadrant and mesh the gears until a slight clearance is obtained between the mating teeth. Tighten all nuts securely. Proper adjustment is made when a smooth action is obtained. No adjustment is complete until all guards have been properly replaced.

Periodic oil changes. When a lathe is run daily the oil should be changed in the headstock reservoir about every 6 months. A good grade of machine oil, SAE 20 or 30, should be used. The operator's instruction manual will state the grade of oil that should be used for the various machines. When changing oil in the reservoir, the plugs should be removed and the reservoir flushed with kerosene before refilling. The machine should be left running during the flushing process. All bearings fitted with oil cups should be oiled daily or as often as necessary. The performance of a lathe depends on the attention it receives. During the first 3 or 4 days or "the breaking in period," all bearings should be carefully oiled and watched to see that none run hot.

This will conclude Volume II after you answer these last few questions. But, don't give up yet, though. There are still two volumes left!

Exercises (275):

1. To be sure a lathe remains in good condition, it must be periodically checked. What things should be included in these checks?

2. Where are gibs located on the lathe?

3. What should you be sure of before you attempt to adjust spindle bearings?

4. What condition can be checked by engaging the half nut and moving the carriage back and forth by hand?

5. Describe the procedures for changing oil in the headstock.

Bibliography

Books

Oberg, Erik, and Franklin D. Jones. *Machinery's Handbook*, 19th Edition. New York: Industrial Press, 1974.

Colvin, Charles H., Henry F. Colvin, and Eleanor Stanley. *The New American Machinist's Handbook*. New York: McGraw Hill Book Company, 1973.

Walker, John R. *Modern Metalworking*. Illinois: The Goodheart-Willcox Company, Inc. 1973.

Department of the Air Force Publications

AFR 127-101, *Accident Prevention Handbook*.

TO 1-1A-9, *Engineering Series for Aircraft Repair—Aerospace Metals—General Data and Usage Factors*.

TO 34-1-10, *Fundamentals of Ordnance Corps Machine Tools*.

TO 42B-1-6, *Corrosion Prevention Lubricants and Anti-Seize Compounds*.

TO 42B2-1-3, *Fluids for Hydraulic Equipment*.

NOTE: None of the items listed in the bibliography above are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell AFB AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only *books* and a limited number of *AFMs*. TOs, classified publications, and other types of publications are *not* available. Refer to current indexes for the latest revisions of and changes to the official publications listed in the bibliography.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:
200 - 1. A ferrous metal is any metal that has iron as its main element.
200 - 2. A nonferrous metal is any metal that contains less iron than any other metal.
200 - 3. a. Nonferrous.
  b. Nonferrous.
  c. Ferrous.
  d. Ferrous.
  e. Ferrous.
  f. Nonferrous.
  g. Nonferrous.
200 - 4. To steel that contains one or more elements other than the iron and carbon which comprises steel.

201 - 1. The steel contains .95 of one percent carbon.
201 - 2. 4140 is a molybdenum steel and is broken down as follows;
  4 Molybdenum steel
  1 1 percent molybdenum
  40 .40 of one percent carbon
201 - 3. AISI-C1040.
201 - 4. For materials used in the manufacture of aircraft and various accessories.
201 - 5. AMS-5095C.
201 - 6. Military Specifications (MIL) and Joint Army-Navy Specifications (JAN).
201 - 7. AA-4024: 4 Silicon alloy
  0 No control of impurities used
  24 Manufacturer's designation
201 - 8. Commercially pure aluminum containing 100 percent aluminum.
201 - 9. The chemical composition of the metal.

202 - 1. Stencil, color code, and stamping.
202 - 2. The Federal or Military Specification number.
202 - 3. N indicates a normalized temper and is depicted by the color gold; Q indicates that the metal is aircraft quality and is depicted by the color silver.
202 - 4. Because the portion of the metal which has been stamped must usually be discarded prior to using the metal for work stock.

203 - 1. The toughness decreases.
203 - 2. Tensile strength is a substance's resistance to being slowly pulled apart.
203 - 3. By varying the hardness of the metal.
203 - 4. Ductility is a material's ability to stretch without breaking.
203 - 5. Stress is the internal reaction to an external force while strain is the dimensional change in the material as a result of stress.

204 - 1. Sulfur and phosphorus.
204 - 2. Vanadium.
204 - 3. Cams, gears, landing gear cylinders, bombracks, and bolts.
204 - 4. Molybdenum steels (SAE-4000 series).
204 - 5. High carbon steels, tungsten steels, chromium-vanadium, and silicon-manganese steels.
204 - 6. Nickel and chromium.
204 - 7. They are highly corrosion and heat resistant.

205 - 1. The aluminum-copper alloys (AA-2000 series).
205 - 2. To the coating of pure aluminum over certain aluminum alloys to make them more corrosion resistant.
205 - 3. Manganese (AA-3000 series), silicon (AA-4000 series), and magnesium (AA-5000 series).
205 - 4. They both present fire hazards during machining because the small chips and dust from both metals are flammable.
205 - 5. Inconel "X" has aluminum, columbium, and titanium additives which make it harder and stronger than inconel.
205 - 6. Brass is an alloy of copper and zinc; bronze is an alloy of copper and tin.
205 - 7. Phospher bronze.
205 - 8. Nonferrous metals are generally "free machining." Monel, inconel, inconel "X," and titanium are notable exceptions.

206 - 1. Three.
206 - 2. Heating, soaking, cooling.
206 - 3. Mechanical mixture, solid solution, combination mechanical mixture and solid solution.
206 - 4. By varying the degree of heating and rate of cooling.

207 - 1. Hardening, tempering, annealing, normalizing, and case hardening.
207 - 2. It usually becomes softer, however high-speed steel becomes harder.
207 - 3. Annealing is mainly a softening process in which the rate of cooling must usually be controlled, while normalizing is mainly a toughening process that requires higher temperatures but uncontrolled cooling in air.
207 - 4. A wear-resistance surface and a tough core.
207 - 5. The job that the part must do.
207 - 6. Rockwell C-57 to C-60.

208 - 1. To relieve stresses and brittleness.
208 - 2. It is a hardening process for nonferrous metals in which the metal is heated to a point where the alloy elements go into a solid solution, then quenched, and then precipitated a specific grain structure.

208 - 3. Precipitation hardening is the final step in solution heat treatment and consists of allowing the alloy elements to change or precipitate from a solid solution under controlled conditions to obtain specific grain structures.
208 - 4. To the various heat treatment conditions to which the aluminum has been subjected.
208 - 5. Stabilizing.
208 - 6. All of them.
208 - 7. By cold working.
208 - 8. Little or none.

209 - 1. By making a file test– normally the easier the file cuts, the softer the metal.
209 - 2. The oil in the skin can cause the file to slide over the work giving a false indication of hardness.
209 - 3. The metals processing specialist.
209 - 4. Brale; sphero-conical shape.
209 - 5. It is used to securely seat the penetrator.
209 - 6. The "C" scale and the Brale penetrator.
209 - 7. The hardened steel ball.

CHAPTER 2

210 - 1. To overcome or decrease friction.
210 - 2. It establishes a film between two moving surfaces and allows them to move without metal contact.
210 - 3. It can be used to carry heat away from mechanisms that would normally run hot.

211 - 1. A plain thrust bearing is solid metal (usually bronze or equivalent) bearing in the shape of a washer (either flanged or flat) that is used to resist end movement of a shaft.
211 - 2. It separates the two moving parts so that one can slide in a straight line along the other on a film of lubricant.
211 - 3. Some types of bronze are manufactured with oil impregnated in the metal which allows it to lubricate itself.

212 - 1. Antifriction bearings operate with a rolling motion instead of a sliding motion.
212 - 2. Roller bearings roll on straight or tapered cylinders instead of balls.
212 - 3. Protecting the bearings from abrasive and corrosive deposits that can contaminate the lubricant during operation.
212 - 4. Grease.

213 - 1. In the splash system, the oil is distributed by the teeth of gears which dip into an oil reservoir; the oil in the circulation system is distributed by a pump.
213 - 2. The oil in a ring and chain system is distributed by loosely revolving chains or rings which dip into a reservoir and revolve around the journal that requires lubrication.
213 - 3. Drop-feed cups depend on gravity to dispense the oil; wick-feed oilers depend on capillary action to disperse the oil.
214 - 1. High chemical stability, minimum variation in viscosity with temperature changes, rapid separation from water, maximum resistance to detrimental influence of impurities, and maximum film strength and lubrication.
214 - 2. The lowest viscosity that will maintain a film throughout the temperature range of the mechanism.
214 - 3. Metallic-soap greases.
214 - 4. They cannot disperse heat and they must be attached by bonding or other similar means to the bearing surface.
214 - 5. Consult the operator's manual.

215 - 1. The cushioning effect.
215 - 2. Petroleum-base hydraulic fluid.
215 - 3. Because hydraulic fluids are usually flammable and must therefore be stored in properly marked and located buildings in the same way as other flammable liquids and they must be stored in containers that can be sealed to prevent contamination of the oil.

216 - 1. The main purpose of a coolant is to carry heat away from the cutting tool; the main purpose of a cutting lubricant is to reduce cutting forces.
216 - 2. Because the coolant can be directed at the cutting edge of the tool and the chip interface to achieve maximum effectiveness from the coolant.
216 - 3. Sulfurized oil.
216 - 4. When sal soda is added to emulsify the solution.
216 - 5. a. Mineral oils; b. soluble oils; c. mineral and lard oil combination; d. soluble oils.

CHAPTER 3

217 - 1. The base and vise.
217 - 2. The vise. The size is determined by the largest piece of stock that can be held in the vise and sawed.
217 - 3. The motor should be shut off.
217 - 4. The ratchet and pawl.

218 - 1. The sawing speed must be correct; the work must be properly positioned and secured; and the correct saw blade must be used.
218 - 2. It is decreased.
218 - 3. Put a 2-inch piece of scrap in the opposite end of the vise so that the jaws remain parallel.
218 - 4. Install a coarse-pitched (6 to 10 teeth per inch) blade; increase the speed; and increase the feed.

219 - 1. They twist the band so that the teeth are in the proper cutting position between the two band guides.
219 - 2. The movable adjusts to the stationary jaw.
219 - 3. The reservoir stores the hydraulic fluid and the pump pumps the fluid to the raising and lowering cylinder for the support frame and also to both the band tension mechanism and the feed mechanism.
219 - 4. Clean it!
219 - 5. The condition of the saw band (condition and pitch of the teeth) and the hydraulic fluid level.

220 - 1. A high-speed abrasive wheel is fed into the work.
220 - 2. It produces smooth surfaces on both sides of the cut and it can cut extremely hard metals.
220 - 3. It cannot be used efficiently for cutting most nonferrous metals.

221 - 1. a; d; f.
221 - 2. b.
221 - 3. c; e; f.
221 - 4. The variable speed unit consists of two stationary outside cones and one adjustable center cone which together form two pulleys. As the center cone is moved from side to side, the ratio between the two pulleys is changed, causing a change in the speed of the saw band.

222 - 1. e.
222 - 2. d.
222 - 3. b.
222 - 4. g.
222 - 5. a.
222 - 6. a.
222 - 7. c.
222 - 8. f.
222 - 9. The set.
222 - 10. 14 pitch.

223 - 1. It should be cut across the gullets from the back toward the teeth.
223 - 2. d; b; c; f; h; e; a; g; i; l; j; k.
223 - 3. Safety goggles should be worn because of the grinding operation and great care should be taken to keep from touching the welded area, especially when the band is installed in saw immediately after welding.

224 - 1. The shoulder rivet beneath the gate segment locks into a slotted hole in the band portion of the other end segment and a dowel rivet beneath the gate segment aligns the two segments and prevents the shoulder rivet from slipping out of the slotted hole.
224 - 2. A flat bastard band, ½ inch wide with a 16-20 pitch.

225 - 1. A 150 grit band.
225 - 2. The polishing band guide is fastened to the guidepost (in the machine head) and the guide support is fastened to the keeper block just below the table. The guidepost should then be lowered until the band guide can rest on the guide support.

226 - 1. The upper guide block is secured to the lower end of the guidepost with two thumbscrews; the lower guide block is secured to a keeper block under the table with a thumbscrew and dowl pin.
226 - 2. Loosen the tilt locknut; turn the tilt screw and the upper wheel until the band tracks lightly on the guide roller; then retighten the tilt locknut.
226 - 3. There is no hard-and-fast rule, but it is generally better to have the band too tight than too loose.

227 - 1. Place the transmission in neutral.
227 - 2. The file guide mounts to the guidepost and the file guide support mounts to the keeper block below the table. The lower end of the file guide rests in the proper size slot in the guide support. Together they provide support for the file band at the point of contact with the work.
227 - 3. 16-inch radius because smaller bends could cause the band to kink.

228 - 1. The type of the material to be cut, and the thickness of the material.
228 - 2. The recommended speed for titanium and monel is much slower (90-125 fpm) than for most nonferrous metals (700-1500 fpm).
228 - 3. 250 fpm.
228 - 4. Because titanium does not dissipate the cutting heat quickly.
228 - 5. The type of finish that is required.

229 - 1. You should first drill a 1-inch hole in the corner and saw into the hole and then rotate the work 90° and saw out of the hole.
229 - 2. By using a feed block or stick.
229 - 3. Because wider bands cannot easily turn that sharp in the width of kerf that they produce. The band would have to bend which would cause a very rough and hard to control cut and would damage the band.
229 - 4. Constant pressure gives better directional control, smoother finishes, and promotes longer band life.

230 - 1. Drilling a starting hole in the waste part of the work.
230 - 2. The saw band is inserted through the hole in the work, then it is welded, and finally mounted with the work resting on the table and the band in the hole ready to begin sawing.
230 - 3. The saw band is cut close to one side of the weld, the part is removed, and the weld is cut completely out of the band before it is welded together again.

231 - 1. Use a steady light pressure on the work and move the work slowly from side to side.
231 - 2. Start with a coarse grit band and finish with a fine grit band.
231 - 3. Because the width of the polishing band and guide prevent their use in small areas.
231 - 4. Chips build up in the internal area and get under the work making it out of square with the table.

232 - 1. On most contour machines, it must be moved to the lower of two sets of mounting holes in the keeper block.
232 - 2. Measure the angle formed by the guidepost and the table top with a protractor head and blade.

233 - 1. Deciding on the sequence of cuts and laying out the work accordingly.
233 - 2. You must consider which pieces of waste should be left for support during other parts of the cutting operation.

233 - 3. They can be drilled and bolted; welded along the sides; or soldered along the sides in the base of small parts.
233 - 4. The stock will become top heavy and dangerously difficult to handle.

234 - 1. To saw hardened steel that otherwise could not be cut.
234 - 2. A dull band should be selected and mounted upside down.
234 - 3. Between 7000 SFS and 14,000 SFS, depending on the material.

235 - 1. The power is provided by a weight on a beam; as the weight is moved farther out on the beam, more pull or pressure is applied to the work.
235 - 2. Through the use of a cable and chain.
235 - 3. A handwheel on the front of the machine adjusts the position of the weight on the beam and thus varies the amount of feed. The attachment is accuated by releasing a foot pedal slowly until the cable and chain become tight.

236 - 1. The magnifying attachment is clamped to the guidepost and a special connector fits a special outlet on the front of the machine. It is then swung into position over the work to magnify and illuminate intricate cutting operations.
236 - 2. A cylinder bar which is clamped to the guidepost; an adjustable arm which fits on a cylinder bar and is used to set the required radius; and a centering pin which fits into the arm and into the center hole of the disc to be cut and which acts as the pivot pin for the cutting operation. All the parts together are used to align and guide work in the contour machine so that accurate circular discs may be cut.

237 - 1. The angular saw guides are designed to allow especially long work to be cut on the contour machine. They twist the saw band 30° so that the work can be cut off square while laying catercorner across the table.
237 - 2. The rip fence is used to make long straight cuts that are parallel to the side of the work. Accurate results depends on the way the rip fence is aligned and the condition of the saw band.
237 - 3. Both mitering attachments are used for cutting off, mitering, and ripping. The main difference is that the all-purpose mitering attachment has a graduated scale for setting various angles, whereas the other one must be set with a protractor.

238 - 1. Place shims under the base until the guidepost is aligned with the keeper block and in a vertical position.
238 - 2. Put a few drops of oil in the two oil fillers on the welder panel. About once a month is sufficient.
238 - 3. Only with powdered graphite which is into the air intake. Oil will collect dirt around the vanes and cause them to stick.
238 - 4. If the tires are not too far gone, they can be removed, turned inside out, and then reinstalled; if they are badly worn, the tires should be replaced with new ones.

CHAPTER 4

239 - 1. The sensitive drill press can be either floor or bench mounted, is hand fed, and provides the operator with the greatest possible feel of the cutting action. It is used to drill small holes at a high speed.
239 - 2. The radial drill press is capable of performing the functions of several types of drill presses. The spindle of the radial drill press can be positioned over the work, while the work must be positioned under the spindle in the plain drill press.
239 - 3. a. base; b. head; c. column; d. base; e. head; f. arm; g. head; h. arm.

240 - 1. The shank is the part of the drill directly behind the flutes which is used to hold and secure the drill; the body is the part between the point and the shank and contains such parts as the flutes, web, and margin; the point is the cone-shaped cutting end of the drill and contains the cutting lips and the chisel edge.
240 - 2. Because they can be more positively locked into the drill press spindle.
240 - 3. The rose reamer is designed to cut only with the 45° bevel on the end of the flutes, while the standard fluted reamer is designed to cut along the entire length of the flutes. They also have more teeth and thinner lands than the rose reamer.
240 - 4. 60° 82°, 90°, and 100°.
240 - 5. Spot facing or recessing screws or bolts that require a flat bottomed seat.

241 - 1. A fairly close grained wheel of medium hardness.
241 - 2. Dressing and truing; dressing is reconditioning the abrasive surface of the wheel; truing is restoring the wheel's concentricity in relation to its axis.
241 - 3. It should be backed off from the wheel sufficiently to allow the legs of the Huntington dresser to hook over it; it should be repositioned approximately 1/8 inch from the wheel.

242 - 1. 12° to 15° clearance angle and 118° included angle.
242 - 2. Sharper included angles for softer materials; flatter points for harder materials.
242 - 3. By grinding the face of the cutting edge parallel with the drill axis to reduce the shearing effect of the cutting edge.

243 - 1. The drill bit should pivot on your fingers and be held at an angle to the wheel equal to ½ the included angle with the lip cutting edge (the one to be ground) parallel to the axis of the wheel. The clearance angle is then produced by pivoting the shank of the drill downward.
243 - 2. One method is to use a rounded wheel and grind a small portion of the cutting edge face as well as a portion of the lip clearance surface. Another method is to use a sharp edged wheel to notch the back portion of the lip clearance surface toward its corresponding cutting edge, but without actually grinding either of the cutting edges.

243 - 3. Mark a 3 x 8½ piece of paper between 1¾ inches (for an angle of approximately 15°) and 2 inches (for an angle of approximately 12°) from the lower left side and bring the upper right-hand corner into contact with the mark. Then insert the drill bit and compare the angle made with the paper with angle of the drill bit clearance angle.

243 - 4. A drill grinding gage or a protractor head and blade.

244 - 1. To locate and secure tapered shank drill bits, drill chucks, and socket and step reducers.

244 - 2. Partially by friction between the bit and spindle and partially by the location of the drill bit tang in the tang receptacle within the spindle.

244 - 3. Clean both mating parts and remove all burrs.

245 - 1. Support the work on parallels.

245 - 2. Clamps or straps.

245 - 3. Mount the part on the table so that the angle from the 30° hole can be obtained by tilting the table. Then drill all but the angled hole first. Next, tilt the table and drill the angled hole.

246 - 1. By supporting the work on parallels.

246 - 2. Because the surface foot speed increases as the diameter of the drill increases, even though the rpm remains the same.

246 - 3. $\text{RPM} = \dfrac{4 \times \text{CFS}}{\text{drill dia.}}$

$$\text{RPM} = \frac{4 \times 35}{0.500}$$

$$\text{RPM} = \frac{145}{0.500}$$

$$\text{RPM} = 290$$

247 - 1. In the step cone pulley system, the drive belt is moved from one step to another on two stepped pulleys by operating a speed change lever while the spindle is rotating.

247 - 2. First the machine must be shut off. Then the motor can be swiveled enough to allow the belt to be repositioned on another step on the pulleys.

247 - 3. By positioning gear change levers on the speed change gearbox while the machine is *not* operating.

248 - 1. The layout work.

248 - 2. Use shims under any area that may pull down under the pressure of the holddown clamps.

248 - 3. The work should be mounted in a vise. It will provide a better holding surface and the extra weight will help prevent it from spinning if the bit should catch.

248 - 4. It should be tapped into the spindle socket after the tang has been properly aligned in the socket.

248 - 5. Stop drilling and sharpen the drill bit. A dull bit generates excess heat and can cause the part to work harder.

248 - 6. A drill blank that is the diameter of the hole should be held in a drill chuck and the spindle should be lowered so that the blank extends through the drilled hole. Then the part should be clamped to the table or in the vise. The blank should be checked during clamping to be sure it remains free to slide up and down in the hole.

248 - 7. Because the uneven surface will cause an intermittent cut until the cutter teeth are in contact all around the hole. The intermittent cut causes vibration which can loosen the work from its mounting.

249 - 1. Long shirt sleeves should be buttoned or rolled up past the elbows and shirttails should be tucked in. Also, safety glasses should always be worn.

249 - 2. Avoid stopping the chuck by grasping it with the hand.

249 - 3. The drill press should be stopped and the chips removed with a brush or suitable tool; NOT with the hands!

249 - 4. Interrupt the cut several times during the drilling operation.

250 - 1. The foundation that it is to be mounted on and the leveling of the machine.

250 - 2. Start at one point and lubricate all points progressively around the machine.

250 - 3. Wipe the dirt and grit from the column and apply a fresh oil film before raising or lowering the arm when the machine has been idle for a couple of days.

CHAPTER 5

251 - 1. An engine lathe is a general-purpose machine and the toolroom lathe is a more precision built lathe and is designed to produce extremely accurate work.

251 - 2. Primarily for production work.

251 - 3. The size of a lathe is designated by the maximum diameter that can be swung over the ways, the distance between centers, and the overall length of the bed.

252 - 1. The cutting edge is on the left as you look at the point end with the top surface up.

252 - 2. They are located on the side and end of the tool bit and are formed by the intersection of the surfaces below and adjacent to the cutting edge with a plane perpendicular to the base of the tool. They prevent the tool from rubbing on the work.

252 - 3. The side cutting edge angle.

252 - 4. They break up the chips and thus reduce heat buildup in the cutting tool and permit a better flow of coolant to the cutting edge.

252 - 5. The green colored silicon carbide wheel with a 100-120 grain size.

252 - 6. Relief angles; because of the irregularly shaped cutting edge.

253 - 1. Cutting foot speed (CFS) and the diameter of the work that is to be turned.

253 - 2.

$$\text{RPM} = \frac{4 \times \text{CFS}}{\text{work diameter}} \quad \frac{4 \times 80}{4} \quad \frac{320}{4} \quad = 80$$

253 - 3. The more rigid the work setup and the smaller the amount of tool contact, the heavier the feed rate that can be used.

254 - 1. The radius or form is obtained by coordinating the movement of the carriage and the cross-slide while observing the movement of the tool bit.
254 - 2. The speed is too high.
254 - 3. A length of rod equal to the desired radius is placed between the cross-slide and tailstock. The pressure of the cut will keep the rod in place as the cross-slide is power fed across the face of the work.
254 - 4. It mounts directly into the T-slot of the compound rest.

255 - 1. It refers to tapers of only 2° or 3° which, when seated in a socket, tend to lock themselves by friction.
255 - 2. A Morse taper.
255 - 3. The large diameter is the size number divided by 8; the small diameter is the number divided by 10; and the length is the number divided by 2 (all sizes in inches):

number 5 taper = large diameter = ⅝ inch
small diameter = 5/10 inch
length 5/2 = 2½ inches

255 - 4. Self-releasing tapers are steep tapers that are more easily released from a socket than a self-holding taper.
255 - 5. Equally spaced lines are scribed one inch apart on the taper and then checked at the lines with a micrometer. The differences in the readings will give you the amount of taper per inch.

256 - 1. Steep, short tapers.
256 - 2. Use the formula for taper per inch (TPI) and the formula for the tangent of the angle (tan) as follows:

$$\text{TPI} = \frac{\text{LD - SD}}{\text{L of T}} \quad \text{and} \quad \tan \quad = \quad \frac{\text{TPI}}{2}$$

When the tangent of the angle has been computed, the angle may be read from a trigonometric functions table.

256 - 3. The tool bit was not set at center height.
256 - 4. The back of the tool bit rubbing the taper surface as the tool is backed off to be out of the tapered hole.
256 - 5. The file (with a handle) should be held with the tip at about a 10° angle toward the tailstock and with the tip held or guided by the right hand; an abrasive strip should be held with the ends separated and never wound around the work.

257 - 1. The tailstock offset equals the taper per inch dividend by 2 and then that divided multiplied by the length of the work:

$$\text{TO} = \frac{\text{TPI}}{2} \qquad \text{length of work.}$$

257 - 2.

$$\text{Angle} = \frac{\text{included angle}}{2} = \frac{10^\circ}{2} = 5^\circ$$

TO = tan length of work = tan 5° × 10
0.08749 × 10 = 0.8479.
The tailstock should be offset 0.875 inch.

257 - 3. It increases.
257 - 4. After eliminating the backlash in the cross-slide by backing the tailpost slightly away from the tailstock spindle, set the graduated crossfeed collar on zero and then feed the toolpost with the compound rest until a slight drag is felt on a piece of paper held between the post and spindle. Next, back off the crossfeed collar the amount of the required offset. Then, adjust the tailstock laterally until a slight drag is again felt on a piece of paper between the toolpost and spindle. Finally, retighten tailstock clamp screws.
257 - 5. Internal tapers cannot be machined by the offset tailstock method.

258 - 1. The lathe centers stay in alignment when the taper attachment is used; also, the wear on the centers is reduced; and pieces of different lengths can be machined without resetting the taper.
258 - 2. f; g.
258 - 3. e.
258 - 4. a.
258 - 5. c; d.
258 - 6. b.

259 - 1. The guide bar (which is held stationary by a clamp) is set to the proper angle. The guide (which is attached to the cross-slide) travels along the guide bar as the lathe carriage is moved. The movement of the guide bar is at the preset angle and it, therefore, pulls or pushes the cross-slide as it (guide block) travels along the guide bar.
259 - 2. As you position the tool for another cut, make the last movement of the cross-slide away from you.
259 - 3. TPI = 0.0625
TPF = 0.0625 × 12
TPF = 0.750 = ¾
Guide bar setting = ¾

260 - 1. The solid forged-type parting tool must be ground to requirements and is designed to be used without a toolholder; high-speed steel cutter blades are used with special holders and have flank and side relief preground in most cases; tools ground from solid lathe bits are the most versatile since they can be ground to almost any angle, size, or shape, but are used mainly for small work.
260 - 2. Flank relief is the clearance ground on both sides of the parting tool behind the cutting edge and it should be 1° to 2°. Side clearance is the clearance ground on the side surfaces just below the entire length of the cutting surface. An angle of 2° is recommended.

261 - 1. The parting tool should be set at center height and at a right angle to the centerline of the work.
261 - 2. The feed is too fast.

261 - 3. It could cause burns or cuts.

262 - 1. It is the angle formed by the inclination of the thread and a plane perpendicular to the thread axis.

262 - 2. Pitch is the distance from a point on one thread to a corresponding point on the next thread measured parallel to the axis, while pitch diameter is measured at a right angle to the axis and is the diameter of an imaginary cylinder whose periphery passes through the thread at a point where the width of the thread and thread groove are equal.

262 - 3. ¼ = nominal diameter
28 = number of threads per inch
UNF = Unified fine
3 = thread class – lowest tolerance of the three classes
B = internal thread

263 - 1. The thread gage is a go and no-go type gage in which the thread is correctly machined when it fits the "go" portion of the gage but not the "no-go" portion. The thread micrometer measures the pitch diameter of a thread.

263 - 2. $M = \frac{MD - 1.5155}{\text{No. threads}} + (3W)$

$M = 0.250 - \frac{1.5155}{20} + (3 \times 0.029)$

$M = 0.250 - (0.07577) + (0.087)$
$M = 0.17423 + 0.087$
$M = 0.2612$ inch

264 - 1. They are used when the direction of motion is required to be opposite of right-hand threads and when slippage between the part and nut would tend to loosen a right-hand thread.

264 - 2. The relief and rake angles are reversed on left-hand thread cutting tools.

264 - 3. The area at the start of the thread should be undercut to a depth slightly more than the single thread depth and wide enough to allow the threading to have starting room. The first thread should also be chamfered.

265 - 1. Both have included angles of 60°.

265 - 2. The thread and the surface the thread is cut into is tapered at ¾ inch per foot on taper pipe threads while unified threads are straight.

265 - 3. It is aligned in relation to the centerline of the work and not with the taper. It is positioned at center height.

265 - 4. The hole should be drilled or bored straight and equal to or slightly larger than the minor diameter of the small end of the pipe.

266 - 1. Both thread forms have included angles of 60°.

266 - 2. Taper pipe threads are machined on a taper of ¾ inch per foot.

266 - 3. It is positioned in relation to the axis of the work and not in relation to the tapered surface that is to be threaded.

266 - 4. It should be straight bored to a diameter equal to or slightly larger than the minor diameter of the small end of the pipe.

267 - 1. The depth of an Acme is equal to one-half the pitch, plus clearance allowance, and the sides form an included angle of 29°.

267 - 2. The tool should be ground to fit a thread one pitch size smaller than the thread to be cut. It should have 3° to 6° more side clearance than the helix angle of the thread and have 0° side and back rake. The tool should be aligned the same way as for Unified threads, but the compound rest should be set parallel to the ways.

267 - 3. The sides of a square thread are parallel and the depth is equal to the width of the space between the teeth on external threads. On internal threads, the width of the space between the teeth is slightly wider than the depth for clearance.

267 - 4. The internal threading tool must be slightly wider than the one for internal threading.

267 - 5. The tool bit is fed straight into the work and the compound rest is set parallel to the ways.

268 - 1. Change it from millimeters to threads per inch.

268 - 2. $6 : \frac{25.4}{4} = \frac{6 \times 4}{25.4} = \frac{24}{25.4}$ = the desired ratio

$\frac{24}{25.4} \times \frac{5}{5} = \frac{120}{127} = \frac{\text{driving gear}}{\text{driven gear}}$

268 - 3. You multiply the number of teeth on the spindle gear by the number of threads per inch to be cut. Then you divide that by the number nearest to the desired TPI on the quick change gearbox that will make the dividend an even number.

269 - 1. 10 to 30 rpm.

269 - 2. By a tap wrench which is rested on the compound rest.

269 - 3. By light pressure from the end of the tailstock spindle, a drill pad or the jaws of a drill chuck in the case of very small dies.

269 - 4. Insert the chasers into the designated slots, set the desired size (pitch diameter), set the rough/finish lever to "R" and insert the tapered shank into the lathe tailstock. Slide the tailstock carefully toward the chamfered stock. As the die begins to cut, slide the tailstock along with it. Pull backward on the tailstock to open it. Reset the die to the "F" setting and repeat the cutting steps.

270 - 1. For making impressions into the work surface for decoration or to provide a gripping surface.

270 - 2. The knuckle joint type has two rollers in a swivel-type knuckle; the revolving head type has three sets of rollers that can be moved into position by revolving the roller mounting head; and the straddle type has two rollers mounted in jaws that can be opened or closed with an adjusting screw.

270 - 3. There are two patterns, diamond and straight; and there are three pitches for each pattern, fine, medium, and coarse.

270 - 4. Making the setup sturdy enough to support the knurling pressure.

270 - 5. Back the knurling tool away with the cross-slide, reposition it, and start again in a new spot.

270 - 6. Set the tool up as always, but before you start knurling, set the compound rest 50° to the right. This will cause only the right-hand corner to contact the work a little to the left of the right-hand layout line. If it tracks properly, extend the knurl to the layout line. Then move the tool back, position the compound rest back to the original setting and resume the knurling operation.

271 - 1. The centering holes in the grinding wheel spindle should be aligned with the head or tailstock centers.
271 - 2. They are mounted on tapered shafts called quills.
271 - 3. An exploding wheel because of running at too high an RPM.
271 - 4. It should be mounted in a holder which is clamped to the faceplate. The point of the dresser should be set at center height and angled 10° to 15° in the direction of wheel rotation.
271 - 5. Move the wheel away from the work.

272 - 1. On tension springs, the coils lie one against the other in the free state; on compression springs, the coils lie at a set distance apart in the free state. The tension offers resistance to being pulled apart while the compression spring offers resistance to being pressed together.
272 - 2. Steel containing about 1 percent carbon and little or no sulfur or phosphorus.
272 - 3. Phosphorus bronze wire.
272 - 4. The wire is passed through two wood or brass blocks which are pressed together enough to keep the wire tight on the mandrel. The wire is then pulled onto the mandrel by the rotation of the mandrel during the operation.

273 - 1. To prevent springing of slender stock; to provide auxilliary support to permit heavier cuts; to provide support for drilling, boring, or internal work.
273 - 2. Use copper shims between the work and the center rest jaws.
273 - 3. By mounting a cathead on the work.
273 - 4. The follower rest has only two jaws and is mounted to the carriage instead of the ways of the lathe.
273 - 5. 0.001 inch.

274 - 1. Handling, installing, and leveling.
274 - 2. Pad the machine surfaces where the chains will contact the machine.
274 - 3. It must be leveled and then bolted to the foundation.

275 - 1. Such things as lubrication, levelness, bearing condition, gearing, lead screw condition, gibs, and clutches.
275 - 2. On dovetail surfaces of the carriage, cross-slide, and compound rest.
275 - 3. That the trouble does not lie somewhere else.
275 - 4. The end play in the lead screw.
275 - 5. The drain plugs should be removed and then, with the machine running, the reservoir should be flushed with kerosene. Then the plugs should be replaced and the reservoir filled with a good grade of oil in accordance with the operator's manual.

STOP - 1. **MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.**
2. **USE NUMBER 2 PENCIL ONLY.**

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

53150 02 25

METALLURGY AND ADVANCED MACHINE WORK

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet .
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you have to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If mandatorily enrolled student, process questions or comments through your unit trainer or OJT supervisor. If voluntarily enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the Learning Objective Number where the answer to that item can be located. When answering the items on the VRE, refer to the Learning Objectives indicated by these Numbers. The VRE results will be sent to you on a postcard which will list the actual VRE items you missed. Go to the VRE booklet and locate the Learning Objective Numbers for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the best answer to each question.

1. (200) Which of the following metals is identified as nonferrous?

   a. Brass.
   b. Carbon steel.
   c. Gray cast iron.
   d. Chrome-molybdenum steels.

2. (201) All of the following metal identification systems can be used as complete procurement specifications except

   a. Federal Specification Numerical Code.
   b. Society of Automotive Engineers (SAE).
   c. American Society for Testing Materials (ASTM).
   d. Military Specifications (MIL) and Joint Army-Navy.

3. (201) In the Aluminum Association number 7075, the second digit (0) indicates that

   a. the aluminum is 100% pure.
   b. there are no impurities.
   c. no impurity control was used.
   d. there is no alloying element.

4. (202) Stamping the specification number into the metal with metal dies should be used only as a last resort because the stamping

   a. cannot be easily seen.
   b. ruins the surface of the metal.
   c. dies are not readily available.
   d. is very difficult to understand.

5. (203) The shear strength of steel, which is approximately 60 percent of the tensile strength, can be increased by

   a. increasing the ductility.
   b. increasing the hardness of the metal.
   c. increasing the toughness of the metal.
   d. softening the metal without decreasing brittleness.

6. (203) The ability of a material to absorb sudden shock without breaking is known as

   a. toughness.
   b. ductility.
   c. shear strength.
   d. wear resistance.

7. (204) A type of steel that is alloyed with vanadium to form drill rod is

a. low carbon steel.
c. high carbon steel.
b. any carbon steel.
d. medium carbon steel.

8. (204) What type of steel alloys make excellent punches and chisels, but become brittle under impact at subzero temperatures?

a. Molybdenum steels.
b. Chromium-vanadium.
c. Silicon-manganese steels.
d. Chromium-nickel-molybdenum steels.

9. (205) Aluminum alloys whose main alloying element is manganese (AA-3000 series) or silicon (AA-4000 series) are generally

a. heat-treatable.
b. clad with pure aluminum.
c. clad with an aluminum alloy.
d. not hardenable by heat treatment.

10. (205) The characteristic common to both magnesium and titanium is that they are both

a. highly corrosion resistant.
b. fire hazards during machining.
c. approximately the same weight as aluminum.
d. approximately as strong as stainless steel.

11. (206) What are the three basic steps in the various heat treating processes?

a. Heating, soaking, and cooling.
b. Heating, cooling, and annealing.
c. Normalizing, heating, and soaking.
d. Normalizing, heating, and cooling.

12. (207) Which of the following statements is most accurate concerning ferrous metals?

a. All steels must be cooled rapidly to harden them.
b. Most steels must be cooled slowly to harden them.
c. Most steels cannot be hardened by heat treatment.
d. Most steels must be cooled rapidly to harden them.

13. (207) In a case hardened part, the center core is

a. softer than the shell, but tough.
b. softer than the shell, but brittle.
c. harder than the shell, but more ductile.
d. softer than the shell, but less ductile.

14. (208) Nearly all nonferrous metals can be

a. annealed.
b. tempered.
c. case hardened.
d. hardened by heat treating.

15. (209) A tool commonly used by a machinist to check for hardness in a metal is a

a. file.
b. punch.
c. hammer.
d. scraper.

16. (210) The main purpose of a lubricant in a bearing in a piece of shop machinery is to

a. decrease friction.
b. increase friction.
c. assure good metallic contact.
d. smooth out surface irregularities.

17. (211) A bushing can best be described as a bearing that

a. is flanged on both ends.
b. is pressed into a hole.
c. does not require lubrication.
d. is made of something other than bronze.

18. (212) Probably the biggest problem involved with the successful operation of an antifriction bearing is the

a. application of the lubricant.
b. initial lubrication of the bearing.
c. prevention of over-lubrication.
d. prevention of abrasion and corrosion.

19. (213) An oiling system in which the oil is pumped to the machine parts is called a

a. splash.
b. bath system.
c. circulation system.
d. ring and chain system.

20. (214) Which type of grease would be best to use on a mechanism that operates at a high temperature with a churning motion?

a. Straight-soap.
b. Lime-soap.
c. Soda-soap.
d. Metallic-soap.

21. (215) A big advantage of petroleum-base hydraulic fluid over other types is that it

a. is grey in color.
b. is blue in color for easy identification.
c. can be used with a wide variety of temperatures.
d. can be used in abnormally high temperatures of supersonic aircraft.

22. (216) A cutting oil that can cause various types of steel to corrode is

a. lard oil.
b. soluble oil.
c. mineral oil.
d. mineral seal oil.

23. (217) What part of the power hacksaw carries the saw blade?

a. The base.
b. The frame.
c. The swivel vise.
d. The ratchet and pawl.

24. (218) You must saw several lengths of tubing that have varying wall thicknesses. What pitch blade should you choose?

a. 32.
b. 18.
c. 14.
d. 10.

25. (219) On the band cutoff saw, the two band guides

a. twist the saw band.
b. prevent the band from slipping off the drive wheel.
c. prevent the band from slipping off the idler wheel.
d. align the band teeth for cutting between the front guide and the drive wheel.

26. (219) Probably the most abused maintenance requirement on the band cutoff saw is

a. cleanliness.
b. lubrication.
c. band changing.
d. coolant level control.

27. (220) Which of the following best describes the cutting action of the abrasive cutoff saw?

a. The stock is fed into an abrasive band.
b. An abrasive band is fed into the stock.
c. The stock is fed into an abrasive wheel.
d. A grinding wheel is fed down into the work hydraulically.

28. (220) One of the disadvantages of the abrasive cutoff saw is that it does not

a. cut ferrous metals efficiently.
b. cut hardened steel efficiently.
c. leave a smooth finish on the stock.
d. cut most nonferrous metals efficiently.

29. (221) The main purpose of the flexible air line located on head of the contour machine is to

a. cool the work.
b. cool the saw band.
c. keep layout lines free from chips.
d. keep chips out of the saw band teeth.

30. (222) Which of the following is not a contour saw band set pattern?

a. Kerf.
b. Wave.
c. Raker.
d. Straight.

31. (223) After a welded saw band has been heated to a dull cherry red during the annealing process, how should you prevent it from cooling too rapidly?

a. By immersing the weld in warm water.
b. By directing a stream of air over the welded area.
c. By passing the weld back and forth through the thickness gage.
d. By pressing the annealing button several times during cooling.

32. (224) Which statement best describes the way that file band segments are attached to the file band?

a. Both ends of the segment are riveted to the band.
b. The center of the segment is riveted to the band.
c. The leading end of the segment is riveted to the band.
d. The trailing end of the segment is riveted to the band.

33. (225) To be sure that a contour machine polishing band is not mounted backwards, you should check the direction of the

a. abrasive grains on the band.
b. rotation of the upper idler wheel.
c. arrow on the polishing band guide.
d. arrow on the back side of each band.

34. (226) On the contour saw, the lower saw band guide block is mounted with a screw and dowel pin to the

a. underneath side of the filler block.
b. underneath side of the table.
c. keeper block below the table.
d. frame below the table.

35. (227) In a file band setup on the contour machine, the lower end of the file guide rests on the file guide support which is a circular block with

a. two different width slots around its circumference.
b. two different depth slots around its circumference.
c. three different depth slots around its circumference.
d. three different width slots around its circumference.

36. (227) What is the smallest radius or bend that a file band should be subjected to during a file band setup on a contour machine?

a. 6 inch radius.
b. 8 inch radius.
c. 16 inch radius.
d. 25 inch radius.

37. (228) The speed for contour saw bands is given in

a. feet per minute (fpm).
b. cutting foot speed (cfs).
c. teeth per minute (tpm).
d. revolutions per minute (rpm).

38. (228) What determines the amount of feed pressure required for a filing operation on the contour machine?

a. The type of material.
b. The thickness of the material.
c. The shape of the material.
d. The finish required on the material.

39. (229) In straight and contour sawing, which of the following is most applicable concerning the kerf when a filed finish is desired?

a. The kerf should be centered on the layout line.
b. The kerf should be 1/16 inch from the layout line on the waste side.
c. The kerf should be on the waste side and just split the layout line.
d. The kerf should be 1/64 inch from the layout line on the waste side.

40. (229) When sawing radii with the contour machine, it is usually better to drill a hole to produce radii under

a. 1 inch.
b. 3/4 inch.
c. 1/2 inch.
d. 5/8 inch.

41. (230) The first step in an internal sawing operation on the contour saw is to

a. mount and align the saw band and guide inserts.
b. drill a hole in the waste portion of the work.
c. insert the saw band through the work.
d. weld the saw band.

42. (230) When removing the work after an internal sawing operation on the contour machine, what should you do concerning the saw band?

a. Cut anywhere on the band.
b. Cut the previous weld out.
c. Cut through the previous weld.
d. Cut 1 inch above and below the work.

43. (231) When performing a filing operation on the contour machine, a smooth accurate surface can best be produced by moving the work

a. rapidly in one direction with light pressure.
b. slowly from side to side using heavy pressure.
c. slowly from side to side using light pressure.
d. rapidly from side to side with light pressure.

44. (231) When an internal hole must be polished on the contour machine, after the polishing band has been inserted through the hole, the next thing to do is to

a. glue the ends of the band together.
b. tape the ends of the band together.
c. weld the ends of the band together.
d. rivet the ends of the band together.

45. (232) On most contour machines, the lower saw guide must be moved to the lower of two sets of mounting holes in the keeper block when the table is tilted more than

a. 15°.
b. 10°.
c. 20°.
d. 30°.

46. (233) In three dimensional sawing on the contour machine, some waste pieces can be cut off quickly while others must be retained until later in the operation because they

a. are needed for support.
b. have layout lines on them.
c. make good hand holds for feeding the work.
d. can be used in case an error is made in cutting.

47. (233) In a stack sawing operation on the contour machine, the thickness (height) of the stack should be

a. no less than the width.
b. no greater than the width.
c. twice the width or more.
d. no greater than the width plus the length.

48. (234) When selecting and mounting a saw band for the most efficient friction sawing on the contour machine, you should select a

a. sharp band and mount it with the teeth right side up.
b. dull band and mount it with the teeth right side up.
c. dull band and mount it with the teeth upside down.
d. sharp band and mount it with the teeth upside down.

49. (235) On the power feed attachment for the contour machine, the power is provided by

a. a weight on a beam.
b. an electric feed motor.
c. a hydraulic feed motor.
d. a weight on an adjustable handwheel.

50. (236) The diameter of the circle that can be cut with the disc-cutting attachment on the contour machine is limit[illegible] to the

a. length of the adjustable arm.
b. length of the cylindrical bar.
c. size of the picot or centering pin.
d. length of travel of the guide post.

51. (237) On the contour machine, the angular saw guides allow long work to be cut by

a. twisting the saw band 30°.
b. twisting the saw band 45°.
c. aligning the work parallel to the band.
d. aligning the work perpendicular to the band.

52. (238) The contour machine should be installed so the light strikes the table from over the operator's right shoulder when in the

a. sawing position or filing position.
b. filing position and over the operator's right shoulder when in the sawing position.
c. polishing position and over the operator's left shoulder when in the sawing position.
d. sawing position and over the operator's left shoulder when in the filing position.

53. (238) To properly lubricate the air pump on the contour machine, you should

a. pour powdered graphite into the air intake.
b. fill the air pump oil reservoir with light machine oil.
c. rub a graphite stick on the vanes while they are rotating.
d. put a few drops of light machine oil into the vane oil fillers.

54. (239) What type of drill press is designed to always be hand fed to provide a "feel" for the cutting action?

a. Bench.
b. Plain.
c. Radial.
d. Sensitive.

55. (240) Identify the type of machine reamer that produces the smoothest and most accurate hole.

a. A rose reamer.
b. A two fluted reamer.
c. A straight fluted reamer.
d. A reamer with spirally cut teeth.

56. (240) Spot facing on a drill press should be done by using a

a. large diameter reamer.
b. modified drill.
c. counterbore.
d. countersink.

57. (241) Which of the following grinding wheels for the pedestal grinder would be the best choice for general offhand drill sharpening?

a. A close grained hard wheel.
b. A loose grained soft wheel.
c. A loose grained wheel of medium hardness.
d. A fairly close grained wheel of medium hardness.

58. (242) The recommended included angle on drill bits intended for general drilling operations on carbon steel is

a. 100°.
b. 118°.
c. 125°.
d. 150°.

59. (243) You should never raise the shank higher than the cutting edge while you are grinding because it will

a. damage the grinding wheel.
b. produce too much clearance.
c. produce a negative cutting edge angle.
d. produce a positive cutting edge angle.

60. (243) A good method of checking the clearance angles of a drill bit is to use a

a. protractor head.
b. drill grinding gage.
c. protractor head and blade.
d. 3 inch by 8 1/2 inch strip of paper.

61. (244) The type of taper commonly found in the spindle of a drill press is which, if any, of the following?

a. Best.
b. Jarno.
c. Morse.
d. Brown and Sharpe.

62. (245) The table on most radial drill presses can be used to hold work on one of

a. three mounting surfaces on the top and each side.
b. two mounting surfaces at 45° to each other.
c. two mounting surfaces at 90° to each other.
d. two mounting surfaces on each side of the table.

63. (246) What should the spindle RPM be in order to obtain a cutting foot speed of 250 for drilling a piece of brass with a 1/2 inch drill bit?

a. 125.
b. 800.
c. 1250.
d. 2000.

64. (247) To change the speed on a drill press that provides various speeds through the use of a speed change crank and the step cone and belt system, move the

a. front pulley with the machine running.
b. belt by hand with the machine stopped.
c. speed change crank with the machine stopped.
d. speed change crank while the drill press is in operation.

65. (248) On small bench-mounted drill presses that have no provision for securing anything to the table, you should not use drill bits larger in diameter than

a. 1/4 inch.
b. 5/16 inch.
c. 10 millimeters.
d. 15 millimeters.

66. (248) The recommended speed for machine reaming is

a. 1/4 the normal drilling speed.
b. 1/2 the normal drilling speed.
c. twice the normal drilling speed.
d. the same as the normal drilling speed.

67. (249) To prevent chips from becoming dangerously long during a drilling operation, you should

a. use power feed only.
b. pull the chips away as they are formed.
c. interrupt the feed regularly to break the chip.
d. vary the speed during the drilling process.

68. (250) Before you raise or lower a radial drill press that has been idle for a couple of days, you should

a. make sure the hydraulic reservoir is full.
b. place the speed change gear box in neutral.
c. operate the feed motor for about 10 minutes.
d. clean the column and apply a fresh oil film.

69. (251) Which of the following types of lathes is designed specifically for producing extremely accurate work?

a. Bench.
b. Turret.
c. Engine.
d. Toolroom.

70. (252) What lathe tool bit relief angle is most effected by the 14 1/2° tool holder angle?

a. End.
b. Side.
c. Back.
d. Rake.

71. (252) Grinding relief angles on lathe form tool bits is more difficult than on other type bits because of the

a. angle of the toolholder.
b. irregularly shaped cutting edge.
c. necessity for more than the regular clearance.
d. different type of grinding wheel which must be used.

72. (253) According to RPM formula, what lathe spindle RPM would be required to turn a 1 inch piece of carbon steel when you have selected a cutting foot speed (CFS) of 80?

a. 80.
b. 160.
c. 320.
d. 400.

73. (254) Which method of cutting radii on the lathe requires the coordinated movement of the carriage and cross-slide while you observe the cutting action?

a. Radius rod.
b. Compound rest.
c. Template and painter.
d. Hand manipulation.

74. (255) Tapers with angles of only 2° or 3° are called

a. fast tapers.
b. self-holding tapers.
c. self-adjusting tapers.
d. self-releasing tapers.

75. (256) After checking a taper that you are machining with the compound rest on a lathe, you find that the taper-per-inch is not correct even though you have determined that the compound rest angle is accurately set. What is the probable trouble?

a. The tool bit is not set at center height.
b. The tool bit is not parallel to the compound rest.
c. The tool bit is not 1/32 inch below center height.
d. The tool bit is not perpendicular to the compound rest.

76. (256) When you file work which is revolving in a lathe, you should point the tip of the file at a 10° angle toward the tailstock end of the lathe. The handle should be held with your

a. right hand and the file tip with your left.
b. left hand the the file tip with your right.
c. left hand and you should not attempt to hold the tip.
d. right hand and you should not attempt to hold the tip.

77. (257) In the offset tailstock method of machining a taper, when the included angle and the length of work are given, the actual angle to be machined is determined by

a. dividing the included angle by 2.
b. dividing the included angle by 4.
c. multiplying the included angle by 4.
d. multiplying the included angle by 2.

78. (257) With the offset tailstock method of cutting tapers, as the length of the work increases, the

a. amount of taper increases.
b. length of taper decreases.
c. amount of taper decreases.
d. length of taper increases.

79. (258) What part found on many lathe taper turning attachments prevents backlash from developing in the crossslide during operation?

a. The draw bar.
b. The bed bracket.
c. The guide block.
d. The carriage bracket.

80. (259) When a taper is turned with the taper attachment, the tool bit moves lengthwise on a line parallel to the

a. warp of the lathe.
b. taper attachment guide bar.
c. taper attachment draw bar.
d. centerline of the work.

81. (260) The clearance on both sides of a lathe parting tool behind the cutting edge should be ground at 1° to 2° and is called

a. flank relief.
b. end relief.
c. side relief.
d. side clearance.

82. (261) When you are setting up a parting tool in a lathe, the parting tool should be set at

a. slightly below center and angled slightly toward the waste part of the work.
b. center height and angled slightly toward the waste part of the work.
c. slightly above center and at 90° to the center line of the work.
d. center height and square to the work axis.

83. (262) The distance from a point on a thread to a corresponding point on the next thread measured parallel to the thread axis is the

a. lead.
b. pitch.
c. pitch diameter.
d. helix measurement.

84. (263) To accurately measure a thread with a thread micrometer, the micrometer must be the right size (0 to 1 inch, 1 to 2 inches, etc.) and also must be of the correct

a. helix range.
b. pitch range.
c. lead angle range.
d. crest width range.

85. (264) A thread is left-hand if, when viewed axially, it winds in a

a. clockwise and receding direction.
b. clockwise and advancing direction.
c. counterclockwise and receding direction.
d. counterclockwise and advancing direction.

86. (265) To cut a triple lead thread having 18 threads-per-inch, the lathe must be set up to cut

a. 6 threads-per-inch.
b. 9 threads-per-inch.
c. 18 threads-per-inch.
d. 36 threads-per-inch.

87. (266) The nominal pipe size or designation of an external taper pipe thread is the

a. root diameter of the biggest thread.
b. approximate outside diameter of the pipe.
c. approximate inside diameter of the pipe.
d. average pitch diameter of the tapered portion of the thread.

88. (267) The allowance for single depth clearance on an Acme thread should be

a. 0.005 inch on sizes.
b. 0.005 inch on threads of less than 10 per inch.
c. 0.010 inch on threads of 10 per inch or more.
d. 0.010 inch on threads of 10 per inch or less.

89. (268) When you must cut a metric thread on a standard lathe, you must replace driving and driven gears to obtain the correct ratio. One of these replacement gears must have

a. 127 teeth.
b. 100 teeth.
c. 75 teeth.
d. 25 teeth.

90. (269) When tapping in lathe by power, the tap wrench should be secured from turning by resting the handle on the

a. ways.
b. toolpost.
c. compound rest.
d. tailstock spindle.

91. (270) There are two patterns of knurls, diamond and straight line. How many pitches are there for each pattern?

a. 1.
b. 2.
c. 3.
d. 6.

92. (271) Before you stop the rotation of the work during a toolpost grinding operation on a lathe, you should

a. stop the motor.
b. turn the lathe spindle motor off.
c. stop the rotation of the grinding wheel.
d. move the grinding wheel away from the work.

93. (272) If steel wire would corrode rapidly in connection with repair work, use

a. brass wire.
b. music wire.
c. phosphorous bronze wire.
d. spring steel wire.

94. (273) By using the micrometer carriage stop, the tool bit can be positioned

a. lengthwise of the ways to within 0.001 inch.
b. crosswise of the ways to within 0.001 inch.
c. lengthwise of the ways to within 0.0001 inch.
d. crosswise of the ways to within 0.0001 inch.

95. (274) When a lathe must be lifted during installation, it should be lifted with a

a. heavy chain attached to the chuck and tailstock.
b. brass chain.
c. steel chain.
d. heavy rope.

96. (274) To properly check a newly installed lathe to see if it is level, you should check it

a. lengthwise with a precision level.
b. lengthwise with a combination square level.
c. crosswise and lengthwise with a precision level.
d. crosswise and lengthwise with a combination square level.

97. (275) On a lathe, the gibs on the compound rest slide should be adjusted

a. fairly tight when the compound is not being used for cutting angles.
b. very tight if the compound is being used for cutting angles.
c. fairly loose if the compound is not being used for cutting angles.
d. loose no matter how the compound is used.

98. (276) Which valve on a hydraulic press opens automatically when the press reaches its rated capacity?

a. Ram release valve.
b. Safety relief valve.
c. High pressure check valve.
d. High pressure intake valve.

99. (277) What should you do if you desire to reduce the effort required when pumping the hydraulic press?

a. Raise the bolster.
b. Lower the ram extension screw.
c. Bypass the high-pressure plunger.
d. Turn the low-pressure bypass valve stem clockwise until it rests against its stop pin.

100. (278) What can be done to help prevent galling during a press operation?

a. Polish the shaft.
b. Reface the bushing.
c. Add a lubricant to the pressed area.
d. Increase pressure on the pressed part.

END OF EXERCISE

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 44 USC 3101. PRINCIPAL PURPOSE(S): To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with every ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA: MAIL TO ECI, GUNTER AFS, ALA 36118

1. THIS REQUEST CONCERNS COURSE
2. TODAY'S DATE
3. ENROLLMENT DATE
4. PREVIOUS SERIAL NUMBER
5. SOCIAL SECURITY NUMBER ☐☐☐–☐☐–☐☐☐☐
6. GRADE/RANK
7. INITIALS ☐☐ LAST NAME
8. OTHER ECI COURSES NOW ENROLLED IN
9. ADDRESS: (OJT ENROLLEES - ADDRESS OF UNIT TRAINING OFFICE/ALL OTHERS - CURRENT MAILING ADDRESS)

ZIP CODE ☐☐☐☐☐

10. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE:
11. AUTOVON NUMBER
12. TEST CONTROL OFFICE ZIP CODE/SHRED

SECTION II: Old or INCORRECT ENROLLMENT DATA

1. NAME:
2. GRADE/RANK:
3. SSAN:
4. ADDRESS:
5. TEST OFFICE ZIP/SHRED:

SECTION III: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an "X" through number in box to left of service requested)

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. The latest course workbooks have a Form 17 printed on the last page.

1 EXTEND COURSE COMPLETION DATE. (Justify in Remarks)

2 SEND VRE ANSWER SHEETS FOR VOL(s): 1 2 3 4 5 6 7 8 9 - ORIGINALS WERE: NOT RECEIVED, LOST, MISUSED

3 SEND COURSE MATERIALS (Specify in remarks) - ORIGINALS WERE: NOT RECEIVED, LOST, DAMAGED.

4 COURSE EXAM NOT YET RECEIVED. FINAL VRE SUBMITTED FOR GRADING ON (Date):

5 RESULTS FOR VRE VOL(s): 1 2 3 4 5 6 7 8 9 NOT YET RECEIVED. ANSWER SHEET(s) SUBMITTED ON (Date):

6 RESULTS FOR CE NOT YET RECEIVED. ANSWER SHEET SUBMITTED TO ECI ON (Date):

7 PREVIOUS INQUIRY (ECI FORM 17, LTR, MSG) SENT TO ECI ON:

8 GIVE INSTRUCTIONAL ASSISTANCE AS REQUESTED ON REVERSE:

9 OTHER (Explain fully in remarks)

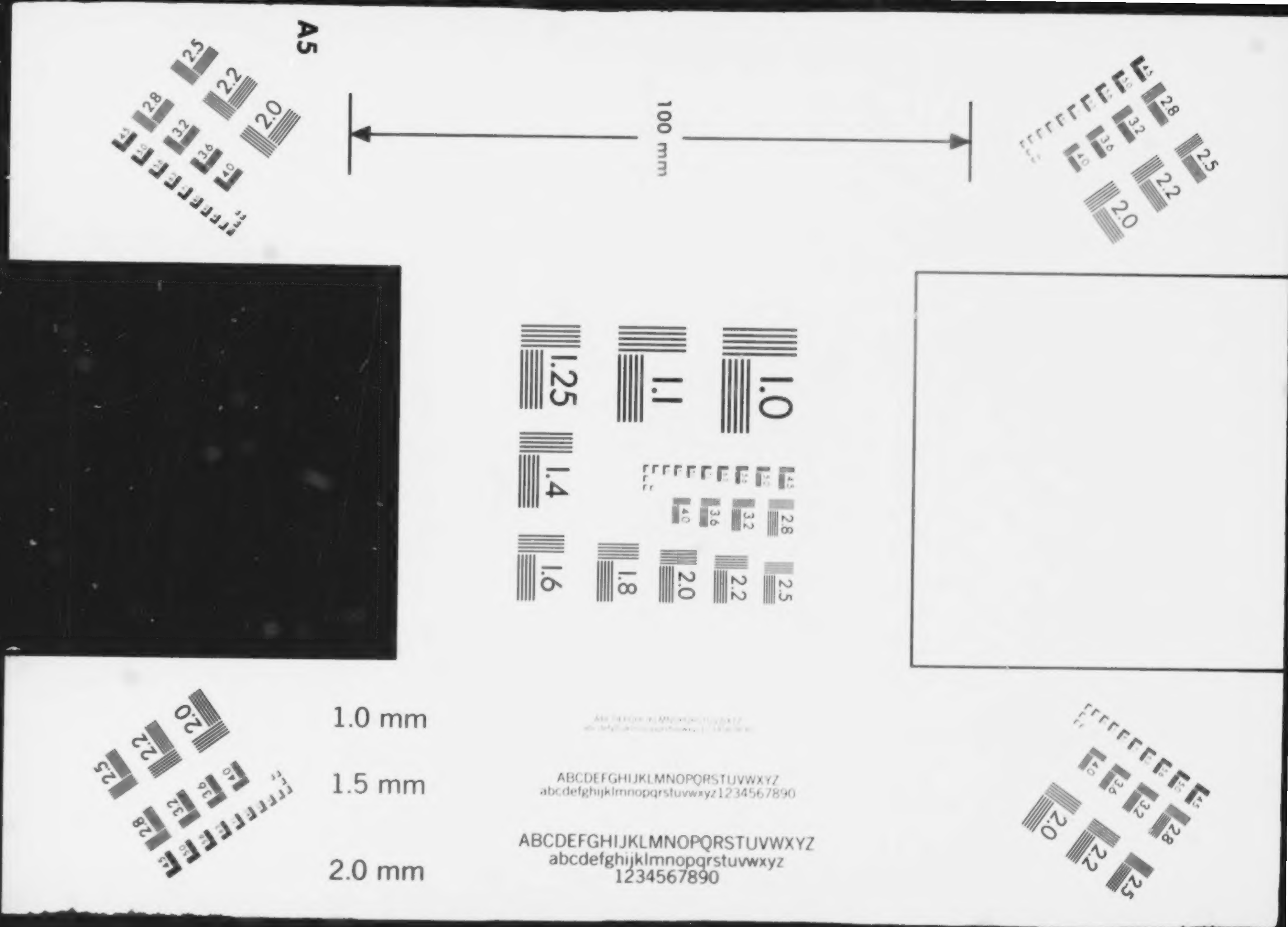
REMARKS: (Continue on Reverse)

OJT STUDENTS must have their OJT Administrator certify this request.

ALL OTHER STUDENTS may certify their own requests.

I certify that the information on this form is accurate and that this request cannot be answered at this station. (Signature)

ECI FORM 17 JUN 77 PREVIOUS EDITIONS MAY BE USED


A5
100 mm
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
PG

1.0 mm

1.5 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890

2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

SECTION IV: REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of textual material should be forwarded directly to preparing agency. Name of agency can be found at the bottom of the inside cover of each text. All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:

MY QUESTION IS:

Course No. ____________

Volume No. ____________

VRE Form No. __________

VRE Item No. __________

Answer You Chose (Letter) ___________

Has VRE Answer Sheet been submitted for grading?

☐ YES ☐ NO

REFERENCE (Textual support for the answer I chose can be found as shown below)

In Volume No: _________

On Page No: ___________

In ______ (Left) _____ (Right) Column

Lines _____ Through ______

Remarks:

53150 03 7701

CDC 53150

MACHINIST

(AFSC 53150)

Volume 3

Advanced Machine Work

Proficimus More Irretenti

Extension Course Institute

Air University

PREPARED BY
MSGT TEDDY L. FORD
3340 TECHNICAL TRAINING GROUP
USAF SCHOOL OF APPLIED AEROSPACE SCIENCES (ATC)
CHANUTE AFB, ILLINOIS 61868

Reviewed by
Eleanor P. Van Cleave, Education Specialist
Extension Course Institute (AU)
Gunter AFS, Alabama 36118

MCMXLVII

Prepared by
3340 Technical Training Group
USAF School of Applied Aerospace Sciences (ATC)
Chanute Air Force Base, Illinois

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

YOU ARE NOW STARTING the second half of CDC 53150, *Machinist*. This third volume covers advanced machine work. Chapter 1 covers milling machine work and Chapter 2 covers shaper work. Chapter 3 is concerned with the various types of grinding operations that you may be required to do and Chapter 4 is concerned with the various aspects of fitting and assembling machined parts.

Code numbers appearing on figures are for preparing agency identification only.

Please note that in this volume, we are using the singular pronoun *he, his,* and *him* in its generic sense, not its masculine sense. The word to which it refers is person.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOX, Chanute AFB IL 61868. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of September 1976.

Contents

Page

Preface iii

Chapter

1 Milling Machine Work 1

2 Shaper Work 34

3 Grinding Machine Work 51

4 Fitting and Assembly 75

Bibliography 82

Answers for Exercises 83

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the object and its text.

Milling Machine Work

MANY YEARS AGO a machinist, whose name is unknown to us now, placed a mandrel, upon which he had mounted a cutter, between the centers of a lathe, fastened the object he was machining to the lathe's cross-slide, and invented the milling machine! From this simple invention, one of the most versatile and important metal cutting machines in existence, the modern milling machine, has evolved. In this chapter we will discuss milling cutters and arbors, milling operations, milling machine attachments, gear cutting procedures, and milling machine maintenance.

1-1. Cutter and Arbor Selections

In this section, you will review the basic parts of a milling machine as well as the various types of milling cutters and arbors. Even though you studied this material for your 3 skill level, you must be completely familiar with it because we will refer to various milling machine parts, cutters, and arbors in later text segments in this chapter.

400. Select the best description of each of the main parts of a plain milling machine or a correct statement of its purpose.

Milling Machine Parts. Since the column and knee milling machine is able (if you use the proper attachments) to perform the same operations as the vertical spindle and ram types, we will use it as an example. The parts of the column and knee machine are typical, in most cases, of the parts of the other types of milling machines. Figure 1-1 illustrates a plain column and knee machine, which can be found in many Air Force machine shops.

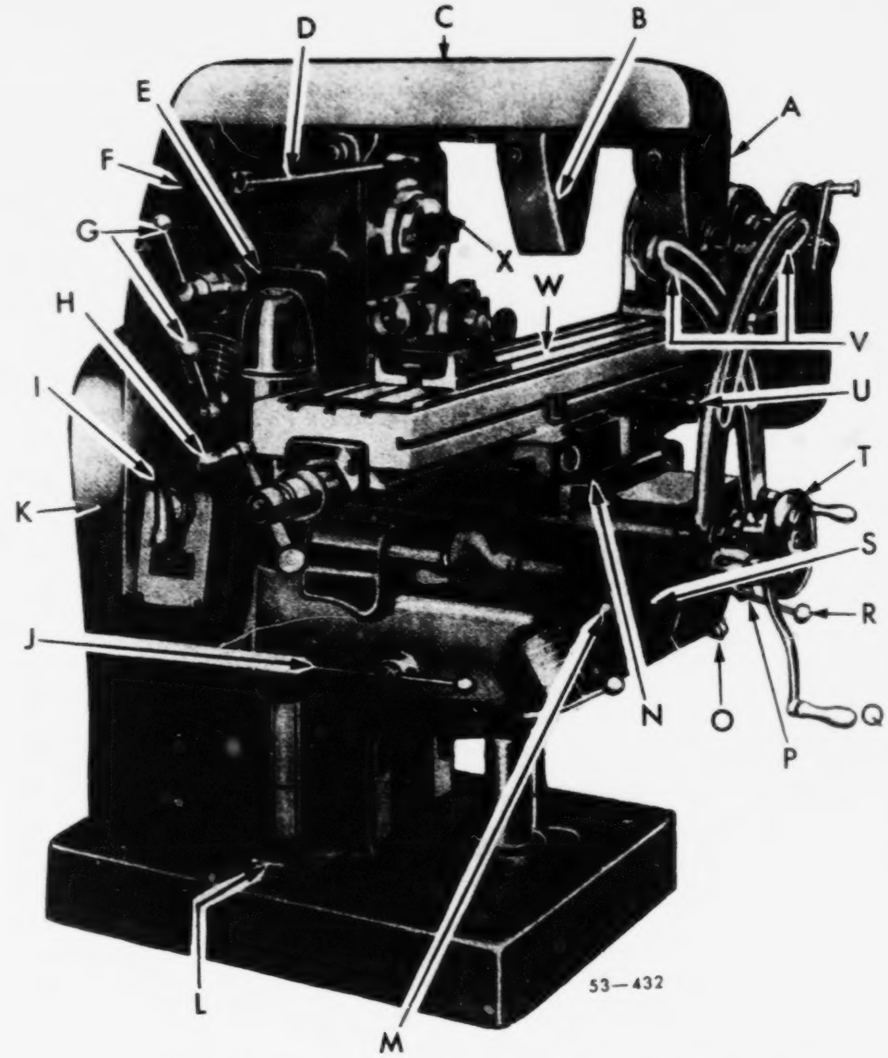
Column. The column (fig. 1-1, F), which is the main casting of a milling machine, is called a column because of its height and shape. The column contains the gearing and drive shafts and an oil reservoir and a pump to supply the spindle with the necessary lubrication. The column rests on a base that contains a coolant reservoir and a pump that you can use when you perform any machining operation requiring a coolant.

Knee. The knee (fig. 1-1, S) is the casting that supports the table and saddle. It acquired its name because it resembles the knee used in building construction to reinforce joints. The knee is fastened to the column by dovetail ways. You can raise or lower the knee by either hand or power feed. You usually use hand feed to take the depth of cut or to position the work, and you use power feed to move the work during the machining operation.

Power feed mechanism. The power feed mechanism, which is contained in the knee, controls the longitudinal, transverse (in and out), and vertical feeds. You can obtain the desired rate of feed on such machines as the one shown in figure 1-1 by positioning the feed selection levers as indicated on the feed selection plate. On some machines, you obtain the feed that you want by turning the speed selection handle until the desired rate of feed is indicated on the feed dial. Most milling machines have a rapid traverse lever to engage when you wish to increase the speed of the longitudinal, transverse, or vertical feeds temporarily. For example, you would engage this lever when you are positioning or aligning the work.

Table. The table is the rectangular casting located on top of the saddle, as shown in figure 1-1, W. It contains several T-slots that enable you to fasten work or workholding devices to it. You can move the table by hand or by power. To move the table by hand, you engage and turn the longitudinal handcrank. To move it by power, you engage the longitudinal directional feed control lever. You can position the longitudinal directional feed control lever to the left, to the right, or in the center. Place the ball end of the directional feed control lever to the left to feed the table toward the left. Place it to the right to feed the table toward the right. Place it in the center position to disengage the power feed or to feed the table by hand.

Spindle. The purpose of the spindle (fig. 1-1, X) on a milling machine is somewhat similar to the purpose of



A. Style B arbor support
B. Style A arbor support
C. Overarm
D. Spindle clutch lever
E. Gear shifter bracket
F. Column
G. Speed control lever
H. Longitudinal handcrank
I. Spindle reverse lever
J. Feed reverse lever
K. Motor behind this cover
L. Centrifugal pump
M. Feed control lever
N. Saddle
O. Vertical feed lever
P. Transverse feed lever
Q. Knee elevating crank
R. Rapid transverse lever
S. Knee
T. Transverse handwheel
U. Longitudinal feed control lever
V. Overarm braces
W. Table
X. Spindle

Figure 1-1. Plain column and knee milling machine.

a lathe spindle. A milling machine spindle normally holds and drives a cutter or a cutting toolholder. A lathe spindle normally holds and drives a workholding device. The spindle extends completely through the column of the milling machine. An internal taper is machined in the front end of the spindle, which is near the table. The internal taper permits you to mount tapered-shank cutter holders and cutter arbors. Two keys, located on the face of the spindle, provide a positive drive for the cutter holder, or arbor. You secure the holder or arbor in the spindle by a drawbolt and jamnut. Large face mills are sometimes mounted directly to the spindle nose.

Overarm. The overarm is the horizontal beam to which you fasten the arbor support. The overarm, shown in figure 1-1, C, may be a single casting that slides in dovetail ways on the top of the column or may consist of one or two cylindrical bars that slide through holes in the column. You position the overarm on some machines by first unclamping locknuts and then extending the overarm by turning a crank. On others, you move the overarm by simply pushing on it. You should extend the overarm only far enough to position the arbor support over the arbor bearing and keep the setup as rigid as possible. You can place arbor supports (fig. 1-1, V), which consist of two arms, on an overarm if you extend one of the bars approximately 1 inch farther than the other bar. Tighten the locknuts after you have positioned the overarm. On some milling machines the coolant supply nozzle is fastened to the overarm. With a split clamp, you can mount the nozzle to the overarm after you have placed the arbor support in position.

Arbor support. The arbor support is a casting that contains a bearing which aligns the outer end of the arbor with the spindle. This helps to keep the arbor from springing during cutting operations. Two types of arbor support are commonly used. Type A, figure 1-1, B, has a small-diameter bearing hole. Type B, figure 1-1, A, has a large-diameter bearing hole. An oil reservoir in the arbor support supplies the bearing surfaces with the necessary lubrication. You can clamp an arbor support at any location on the overarm. Type A arbor supports provide additional clearance below the arbor supports when you are using small-diameter cutters. Type A arbor supports can provide support only at the extreme end of the arbor. For this reason they are not recommended for general use. You can position a type B arbor support at any point on the arbor. Therefore, it can provide support near the cutter, if necessary. For this reason, position the type B arbor support as close to the cutter as possible in order to produce a rigid tooling setup.

NOTE: Before loosening or tightening the arbor nut, you must install the arbor support. This will prevent bending or springing the arbor.

Exercise (400):

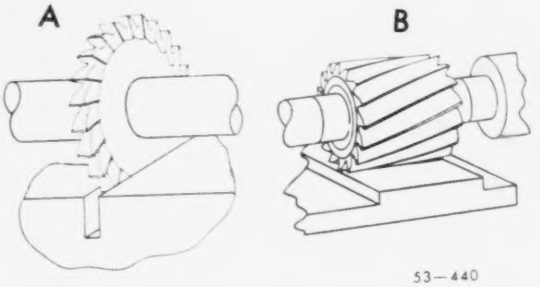
1. Choose the most appropriate statement (description or purpose) on the right with the milling machine part (on the left) to which it applies. More than one statement may apply to some parts.

_____ 1. Column.
_____ 2. Knee.
_____ 3. Power feed mechanism.
_____ 4. Table.
_____ 5. Spindle
_____ 6. Overarm.
_____ 7. Arbor support (type A).
_____ 8. Base.
_____ 9. Arbor support (type B).

a. It holds and drives the cutter.
b. It is contained in the knee and permits the table to be moved by power.
c. It contains an oil reservoir.
d. The saddle is mounted on it.
e. It extends completely through the column.
f. An adjustable horizontal beam.
g. It contains T-slots for mounting work.
h. It has a small diameter bearing hole for certain arbors.
i. It can be moved longitudinally along the saddle.
j. It can be positioned next to the cutter on an arbor.
k. It contains a coolant pump.

401. Describe the characteristics and application of selected types of milling cutters and arbors.

Milling Cutters. *Plain milling cutters* are used to mill flat surfaces that are parallel to the cutter axis. As you can see in figure 1-2,B, a plain milling cutter is a cylinder with teeth cut on the circumference only. Plain milling cutters are made in a variety of diameters and widths with the cutter teeth either straight or helical. If the width is more than3/4 inch, the teeth are usually helical. On a straight cutter, each tooth cuts along its entire width at the same time, causing a shock as the tooth starts to cut. Helical teeth elimilnate this shock and produce a free cutting action. A helical tooth begins the cut at one end and continues across the work with a smooth shaving action. Plain milling cutters usually have radial teeth. On some coarse helical tooth cutters, the tooth face is undercut to produce a smoother cutting action. Coarse teeth decrease the tendency of the arbor to spring and give the cutter greater strength. A plain milling cutter has a standard size arbor hole for mounting if on a standard size arbor. The size of the cutter is designated by the diameter of the cutter, the width of the cutter, and the diameter of the hole.



53—440

Figure 1-2. Side and plain milling cutters.

The *side milling cutter* is a plain milling cutter with teeth cut on both sides, as well as on the circumference of the cutter. You can see in figure 1-2,A, that the portion of the cutter between the hub and the side of the teeth is thinner to provide additional chip clearance. These cutters are often used in pairs to mill parallel sides, called straddle milling. Cutters over 8 inches in diameter usually have inserted teeth. The size designation is the same as for plain milling cutters. Some side milling cutters have coarse, helical teeth on one side only. These cutters are made particularly for jobs where only one side of the cutter is needed.

A type of cutter that is similar to the plain or side milling cutter is the *metal slitting saw*, which is used to cut off work and to mill narrow slots. The face width is usually less than 3/16 inch. This type of cutter usually has more teeth for a given diameter than a plain cutter. It is thinner at the center than at the outer edge to provide proper clearance for milling deep slots. In many slitting saws, the teeth are cut only in the circumference while others have side teeth to achieve better cutting action, break up chips, and prevent dragging when you cut deep slots. For heavy sawing in steel, there are metal slitting saws with staggered teeth. These cutters are usually 3/16 inch to 3/8 inch in thickness.

You will use *angle cutters* to mill surfaces that are not at a right angle to the cutter axis. You can use angle cutters for a variety of work, such as milling reamer flutes and dovetail ways. On such work as dovetailing, where you cannot mount a cutter in the usual manner on an arbor, you can mount an angle cutter that has a threaded hole or is constructed like a shell end mill on the end of a stub or shell end mill arbor. When you select an angle cutter, you should specify type, hand, outside diameter, thickness, hole size, and angle.

There are two types of angle cutters: single and double. In the *single angle* cutter, shown in figure 1-3,A, the teeth are cut at an oblique angle with one side at an angle of 90° to the cutter axis and the other usually at 45°, 50°, or 80°. The *double angle* cutter, figure 1-3,B, has two cutting faces at an angle to the cutter axis. If both faces are at the same angle to the axis, you obtain the cutter you want by specifying the included angle. If they are at different angles, you must specify the angle of each side with respect to the plane of intersection.

You will use *end mill cutters* to mill slots, tangs, and the ends and edges of work. Teeth are cut on the end as well as on the circumference of the cutter. The cutters may be solid with two or more teeth or they may be the shell type. The two-lipped end mill is especially adapted for milling slots without first drilling a hole. It should be used mainly on softer, nonferrous metals and should be operated at a fairly high speed. Figure 1-4 shows a center cutout end mill. You can use this cutter to mill work to a depth of cut equal to the length of the end teeth. *Shell end mills*, shown in figure 1-5, are attached at the end of a taper shank arbor. In most cases, they are more economical than large solid cutter because they are cheaper to replace when they break or wear out.

A *Woodruff keyseat cutter*, figure 1-6, is used to cut curved keyseats. A cutter with less than a 1½ inches diameter has a shank. If the diameter is greater than 1½ inches, the cutter is usually mounted on an arbor. The staggered teeth on the larger cutters improve the cutting action.

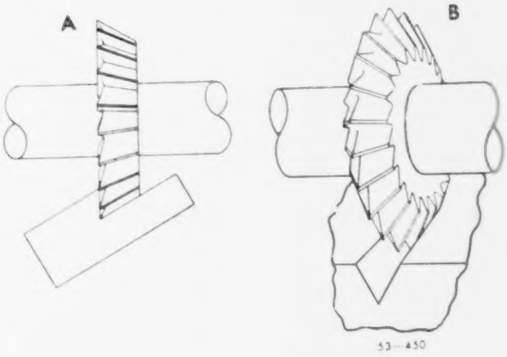


Figure 1-3. Angle cutters.

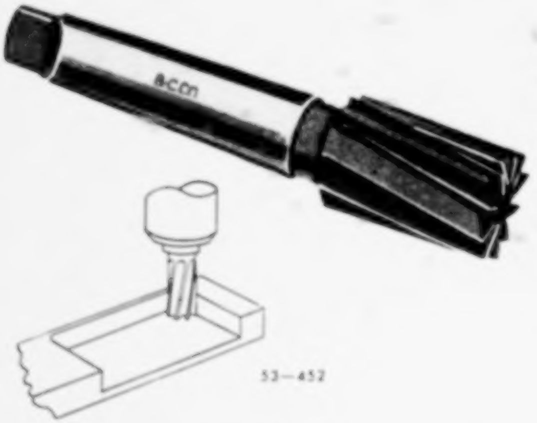


Figure 1-4. End mills.

There are several types of *gear cutters*, such as bevel, spur, involute, etc. Figure 1-7 shows an involute gear cutter. You must select the correct type of cutter to cut a particular type of gear. You use a *concave cutter*, figure 1-8, to mill a convex surface and a *convex cutter*, figure 1-9, to mill a concave surface.

Corner rounding cutters are formed cutters that are used to round corners up to one-quarter of a circle. They are like 1/2 of a convex cutter.

The *gear hob*, figure 1-10, is a formed milling cutter with teeth cut like threads on a screw. You can use it for finishing spur gears, helical gears, worm wheels, etc., and for cutting ratchets and splined shafts.

Arbors. Million machine cutters can be mounted on several types of holding devices. You must know what the devices are and the purpose of each to make the most suitable tooling setup for the operation you are performing. We will cover the various types of arbors and the mounting and dismounting of arbors.

NOTE: Technically, an arbor is a shaft on which a cutter is mounted. For convenience, since there are so few types of cutter holders that are not arbors, we will refer to all types of cutter holding devices as arbors.

There are several types of milling machine arbors. You use the common or standard types, shown in figure 1-11, to hold and drive cutters with mounting holes.

The most common arbors have a standard milling machine spindle taper of 3½ inches per foot. The largest diameter of the taper is identified by a number. For example, the large diameter of a number 40 milling machine spindle taper is 1¾ inches. The numbers designating the sizes of common milling machine spindle tapers are:

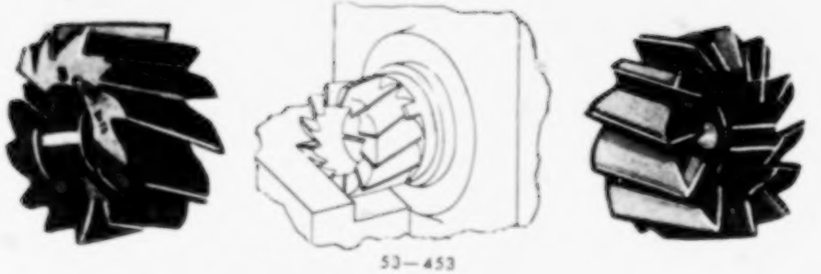


Figure 1-5. Shell end mills.

Number	*Large Diameter*
10	5/8 inch
20	7/8 inch
30	1¼ inches
40	1¾ inches
50	2¾ inches
60	4¼ inches

Standard arbors are available in styles A and B, as shown in figure 1-11. Style A arbors have a pilot-type bearing, usually 11/32 inch in diameter. Style B arbors have a sleeve-type bearing which can be positioned anywhere along the arbor shaft. Numerals identify the outside diameter of the bearing sleeves, as follows:

Sleeve Number	*Outside Diameter*
3	1⅞ inches
4	2⅛ inches
5	2¾ inches

The inside diameter can be any one of several standard diameters that are used for the arbor shaft. Style A arbors sometimes have a sleeve bearing that permits the arbor to be used as either a style A or a style B arbor. A code system, consisting of numberals and a letter, identifies the size and style of the arbor. The code number is stamped into the flange or on the tapered portion of the arbor. The first number of the code indentifies the diameter of the taper. The second (and if used, the third number) indicates the diameter of the arbor shaft. The letter indicates the type of bearing. The numbers following the letter indicate the usable length of the arbor shaft. Sometimes an additional number is used to indicate the size of sleeve type bearings. The meaning of a typical code number, 5-1¼-A-18-4, is as follows:

5 = taper number-50 (the 0 is omitted in the code)
1¼ = shaft diameter-1¼inches
A = style A bearing-pilot type
18 = usable shaft length-18 inches
4 = bearing size-2⅛ inches diameter

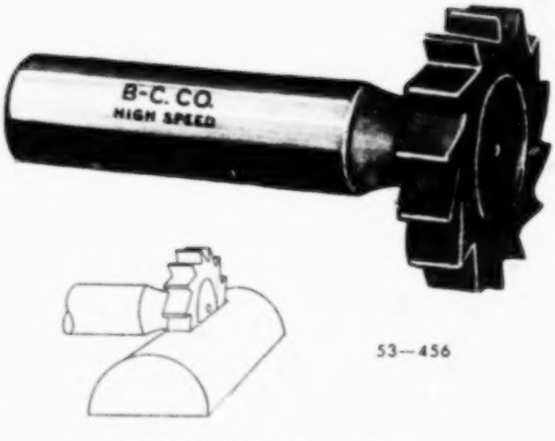


Figure 1-6. Woodruff keyseat cutter.

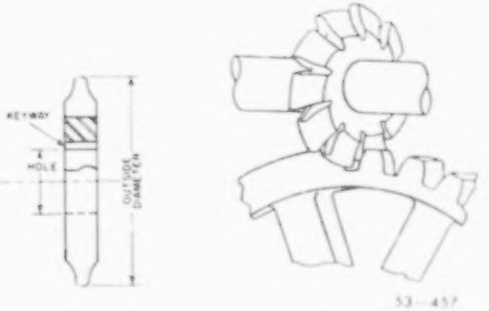


Figure 1-7. Involute gear cutter.

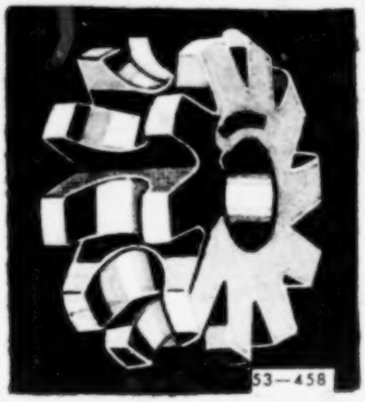


Figure 1-8. Concave cutters.

Arbors with very short shafts are called stubs arbors. They are used when it would be impractical to use a longer arbor and they usually do not require the use of an arbor support.

You will use arbor spacing collars of various lengths to position and secure the cutter on the arbor. The spacers are tightened against the cutter when you tighten the nut on the arbor. Remember, *never* tighten or loosen the arbor nut unless the arbor support is in place. To prevent the cutter from slipping, you insert a square key into the keyway formed by the keyseat that extends the full length of the abor shaft and the keyseat in the cutter.

The Shell end mill arbor, shown in figure 1-12, is used to hold and drive shell end mills. The shell end mill is fitted over the short boss on the arbor shaft. It is driven by two keys while it is held against the face of the arbor by a bolt. You use a special wrench, shown in figure 1-12, to tighten and loosen the bolt. Shell end mill arbors are identified by a code similar to the standard arbor code. The letter C indicates a shell end mill arbor. The meaning of a typical shell mill arbor code, 4-1½-C-⅞, is as follows:

4 = taper code number - 40
1½ = diameter of mounting hole in end mill - 1½ inches
C = style C arbor - shell end mill
⅞ = length of shaft - ⅞ inch

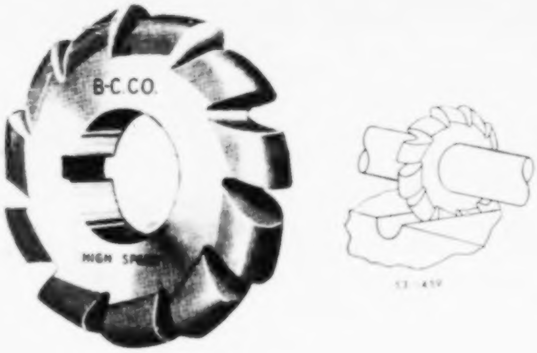


Figure 1-9. Conex cutters.

You use *taper adapters* to hold and drive taper-shanked tools, such as drills, drill chucks, reamers, and end mills, by inserting them into the tapered hole in the adapter. The code for a taper adapter indicates the number representing the standard milling machine spindle taper and the number and series of the internal taper. For example, the taper adapter code number 43M means:

4 = taper identification number - 40
3M = internal taper - number 3 Morse

If a letter is not included in the code number, the taper is understood to be a Brown and Sharpe. For example, 57 means:

5 = taper number - 50
7 = internal taper - number 7 B and S

and 50-10 means:

50 = taper identification number
10 = internal taper - number 10 B and S

Some cutter adapters are designed to be used with tools with taper shanks and a cam locking feature. The cam lock adapter code indicates the number of the external taper, the number of the internal taper (which is usually a standard milling machine spindle taper also), and the distance that the adapter extends from the spindle of the machine. For example, 50-20-3⅝ inches means:

50 = taper identification number (external)
20 = taper identification number (internal)
3⅝ = distance adapter extends from spindle is 3⅝ inches

Cutter adapters are similar to taper adapters except that their holes are always straight, rather than tapered. They are used to hold straight shank drills, end mills, etc. The cutting tool is secured in the adapter by a set-

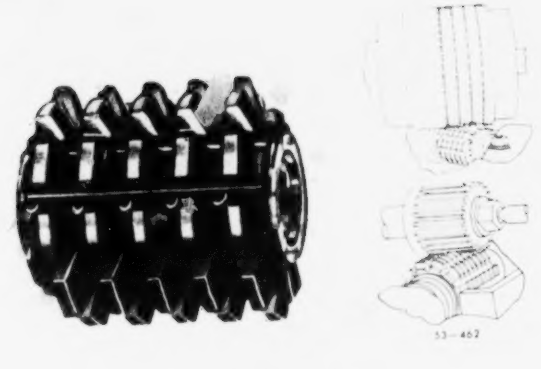


Figure 1-10. Gear hob.

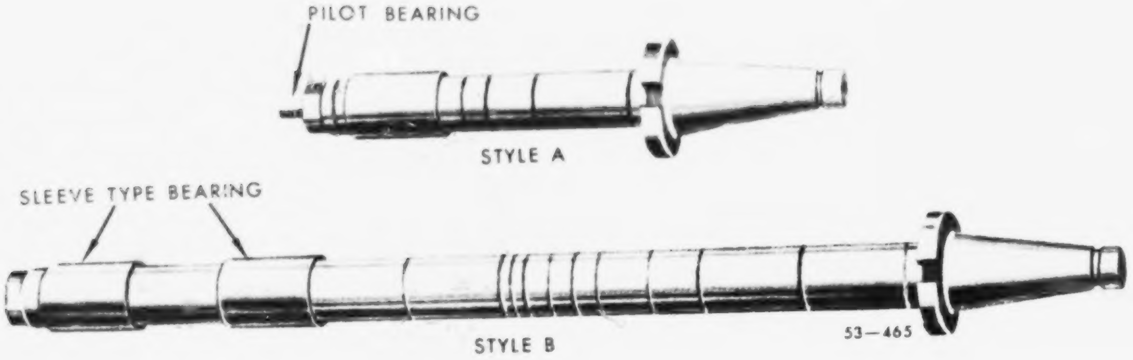

PILOT BEARING
STYLE A
SLEEVE TYPE BEARING
STYLE B
53—465

Figure 1-11. Standard milling machine arbors.

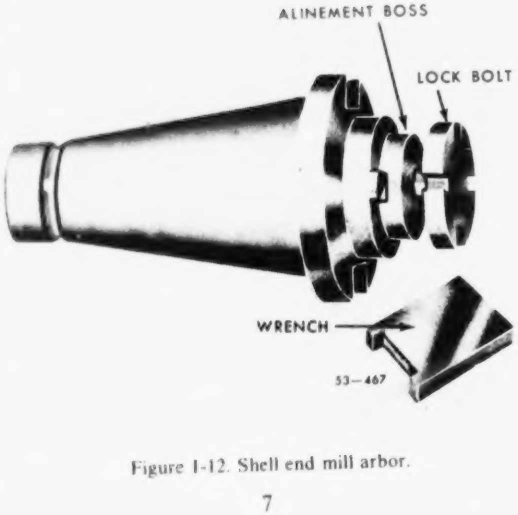

ALINEMENT BOSS
LOCK BOLT
WRENCH
53—467

Figure 1-12. Shell end mill arbor.

screw. The code number indicates the number of the taper and the diameter of the hole. For example, 50-⅝ means that the adapter has a number 50 taper and a ⅝-inch-diameter hole.

Spring collet chucks are used to hold and drive straight-shanked tools. The spring collet chuck consists of a collet adapter, spring collets, and a cup nut. Spring collets are like lathe collets. The cup nut forces the collet into the mating taper, causing the collet to close on the straight shank of the tool. The collets are available in several fractional sizes.

Exercises (401):

1. Briefly describe a side milling cutter and state its main purpose.

2. What cutter characteristics must you consider when you are selecting an angle cutter for a certain job?

3. Describe the difference between large and small Woodruff keyseat cutters.

4. If you measured the large end of a milling machine spindle taper and found it to be 2¾ inch diameter, what is the standard milling machine taper number of an arbor that fits in the spindle properly?

5. Give the meaning of the arbor designation, 4-1-A-12.

6. Give the meaning of the following taper adapter code numbers: 42M, and 58.

7. Describe cutter adapters and state their purpose.

1-2. Milling Operations

As we stated previously, the milling machine is one of the most versatile metalworking machines. It can perform simple operations, such as drilling a hole or milling a flat surface, or more complex operations, such as milling gear teeth. In this section we will discuss its speed and feed requirements as well as such milling operations as plain and face milling, angular milling, boring and fly cutting, slotting, straight flute and keyseat machining, indexing, and graduations milling.

402. Select the proper speeds and feeds for milling specified materials and calculate for rpm and chip thickness.

Calculating Speed and Feed. Which spindle speed should you use? What should the rate of feed be? These are questions that you will ask yourself as you make work and tool setups on a milling machine. Unfortunately, there are no simple answers to these questions. Every job presents a new set of variables that must be considered. You will have to decide which speed and feed to use at the beginning of the machining operation. After observing the cutting action, make any changes that you feel are necessary.

As we explained in drill press work (Volume 2), cutting speed is always given in feet per minute. You must convert cutting foot speed to spindle or cutter speed (rpm). When you use attachments that change the ratio between the rpm of the cutter and the spindle, first determine the cutter speed and then determine the spindle speed. You must consider this ratio and increase or decrease the spindle rpm to give the required cutter rpm. You will remember from our discussion of drill press speed in Volume 2 that a point on the periphery of the cutting tool should travel at a surface-foot speed that is as near as possible to the cutting foot speed recommended for the material you are machining. Also, the diameter of the drill (in this case, the cutter) must be included when you calculate the spindle speed. You can use the same formula to select the milling cutter speed that you use to select the drill speed if you substitute the diameter of the cutter for the diameter of the drill. The formula would then be:

$$\text{rpm} = \frac{4 \times \text{CFS}}{\text{cutter diameter}}$$

Use the lower CFS given in figure 1-13 when you are rough machining and the higher CFS when you are finish machining.

For example: What spindle speed should you use to rough mill low carbon steel with a high-speed steel milling cutter 3 inches in diameter? Figure 1-13 shows that the recommended CFS for rough milling low carbon steel is 80. Therefore:

$$\text{rpm} = \frac{4 \times 80}{3}$$

$$\text{rpm} = \frac{320}{3}$$

$$\text{rpm} = 107$$

To rough mill low carbon steel with a 3-inch cutter, set the spindle speed controls to obtain a speed as near as possible to 107 rpm.

Feed is the rate in inches per minute at which the work is moved into the revolving cutter. The thickness of the chip removed by each cutter tooth as it contacts the work is the basis for determining the feed.

MATERIAL	CUTTING FOOT SPEED
LOW CARBON STEEL	80 TO 110
MEDIUM CARBON STEEL	60 TO 80
HIGH-CARBON TOOL STEEL	50 TO 60
STEEL FORGINGS	50 TO 60
STAINLESS STEEL	30 TO 40
SOFT CAST IRON	100 TO 150
HARD DRILLED CAST IRON	70 TO 100
MALLEABLE IRON	80 TO 90
ORDINARY BRASS AND BRONZE	200 TO 300
HIGH-TENSILE BRONZE	70 TO 150
MONEL	40 TO 150
ALUMINUM AND ITS ALLOYS	200 TO 300
MAGNESIUM AND ITS ALLOYS	250 TO 400
BAKELITE	100 TO 150
WOOD	300 TO 400

53-436

Figure 1-13. Cutting foot speeds.

Climb and Conventional Milling. Climb milling is feeding the work in the same direction as that of the cutter rotation. The thrust of the cut is DOWN or against the work. You use climb milling when the work tends to spring or lift, as in milling thin or easily distorted work. During climb milling, the cutter tends to climb or pull the work into the cutter, and can damage the work or the cutter. To prevent this, make sure that the gibs are snug and that excessive end play (backlash) in the feed screws is removed. You should also tighten the table lock until you feel a slight drag when you use the hand feed. Conventional, or up, milling is feeding the work in a direction opposite to that of the cutter rotation. The thrust of the cut is UP, or away from the work. Use conventional milling whenever the nature of the work and the holding device permit.

Calculating Chip Thickness. The thickness of the chip, or as it is often called, the feed per tooth, is normally from 0.0001 inch to 0.015 inch, but it can be more. Use fine feeds for light finishing cuts and coarse feeds for heavy roughing cuts.

You can determine the chip thickness by multiplying the number of teeth on the cutter by the cutter rpms and then dividing the feed per minute by the product. Determine the chip thickness by using the following formula if you know the feed per minute, the rpm, and the number of teeth on the cutter:

$$\text{Thickness} = \frac{\text{feed}}{\text{teeth} \times \text{rpm}}$$

Example: You are using a cutter with 20 teeth. The rpm is 40 and the feed is 1 inch per minute. What is the chip thickness?

$$\text{Thickness} = \frac{1}{20 \times 40}$$

$$\text{Thickness} = \frac{1}{800}$$

$$\text{Thickness} = 0.00125 \text{ inch}$$

The rate of feed is usually expressed as inches of feed per minute. Most milling machine feed dials are calibrated in inches per minute. You must convert the chip thickness into inches per minute to set the machine for the feed you need. You can do this by using this formula:

$$\text{Feed} = \text{chip thickness} \times \text{number of teeth} \times \text{rpm}$$

Example: You have determined that you should use a speed of 80 rpm and a chip thickness of 0.004 inch to mill the job you are working on. The cutter you have selected has 12 teeth. What feed should you set the machine for?

$$\text{Feed} = 0.004 \times 12 \times 80$$
$$\text{Feed} = 0.048 \times 80$$
$$\text{Feed} = 3.840 \text{ inches}$$

You should set the machine to produce a feed as near as possible to 3.840 inches.

Factors in the Selection of Feeds and Speeds. Varying conditions in milling machine work make fixed rules for cutting speeds and feeds impractical. Generally, you should select a cutting speed that gives efficient cutting action without undue wear on the cutter. Several factors have to be considered in selecting cutter speeds and feeds:

- Hardness of the material. The harder and tougher the metal, the slower the cutting speed.
- Depth of cut and finish desired. Light finish cuts are made at higher speeds than heavy roughing cuts.
- Type of cutter material. High-speed steel cutters can be run at higher speeds than carbon cutters. Carbide cutters can be run faster than high-speed steel cutters.
- Sharpness of the cutter. A sharp cutter always cuts better and more easily than a dull one.
- Coolant. You can operate all milling cutters at faster speeds and feeds when you use a coolant.

Exercises (402):

1. To convert the CFS to rpm for a milling operation in which you are using an attachment that changes the ratio between the cutter and the spindle, what must you do?
2. You must mill a piece of stock and have selected a 6-inch cutter and a CFS of 75. What rpm should you set the machine for?
3. Concerning feed during a milling operation, what precautions should you take when climb milling? Why?
4. What is the normal range of chip thickness for general milling operations?
5. You are milling a part with a cutter that has 15 teeth the rpm is set at 50. With a feed of 1.50 inch per minute, what will the thickness of the chip be?
6. If you have selected a 16 tooth cutter for a milling operation that requires a speed of 60 rpm and a chip thickness of 0.006, what should the feed setting be?
7. How are cutting speeds affected as the hardness of the material to be cut is increased?

403. Describe selected applications and setups for both plain and face milling operations.

Plain and Face Milling. Plain and face milling are the two basic milling machine operations. Both are involved in the milling of all flat surfaces. We will begin with plain milling.

Plain milling. Plain milling is the process of milling a flat surface in a plane parallel to the cutter's axis. You obtain the desired size of the work by milling each of the flat surfaces on the object individually. Plain milling cutters, such as the one shown in figure 1-2, are used for plain milling. Select a cutter that is slightly wider than the width of surface to be milled, if possible. Make the work setup *before* you mount the cutter. This precaution will prevent your accidentally striking the cutter and cutting your hands as you set up the work. You can mount the work in a vise or fixture or clamp it directly to the milling machine table. Use the same methods to hold work in a milling machine that you used to hold work in a shaper. Clamp the work as close to the milling machine column as possible so that you can mount the cutter near the column. The closer you place the cutter and work to the column, the more rigid the setup will be.

Face milling. Face milling is the milling of surfaces that are perpendicular to the cutter axis, as shown in figure 1-14. Face milling produces flat surfaces and machines work to the required length. In face milling, the feed can be either horizontal or vertical.

You can use straight shank or taper shank end mills, shell end mills, or face milling cutters for face milling. Select a cutter that is slightly larger in diameter than the thickness of the material that you are machining. If the cutter is smaller in diameter than the thickness of the material, you will be forced to make a series of slightly overlapping cuts to machine the entire surface. Mount the arbor and cutter *before* you make the work setup. Mount the cutter by the means suitable for the cutter you have selected.

Use any suitable means to hold the work for face milling, provided that the cutter clears the workholding device and the milling machine table. You can mount the work on parallels, if necessary, to provide clearance between the cutter and the table. Feed the work from the side of the cutter that will cause the cutter thrust to force the work down. If you hold the work in a vise, position the vise so that the cutter thrust is toward the solid jaw. The ends of the work are usually machined square to the sides of the work. Therefore, you will have to align the work properly. If you use a vise to hold the work, you can align the stationary vise jaw with a dial indicator. You can also use a machinist square if you rest the base of the square on the machined surface of the column and align the solid jaw of the vise to the blade of the square.

Exercises (403):

1. What is the purpose of plain milling?

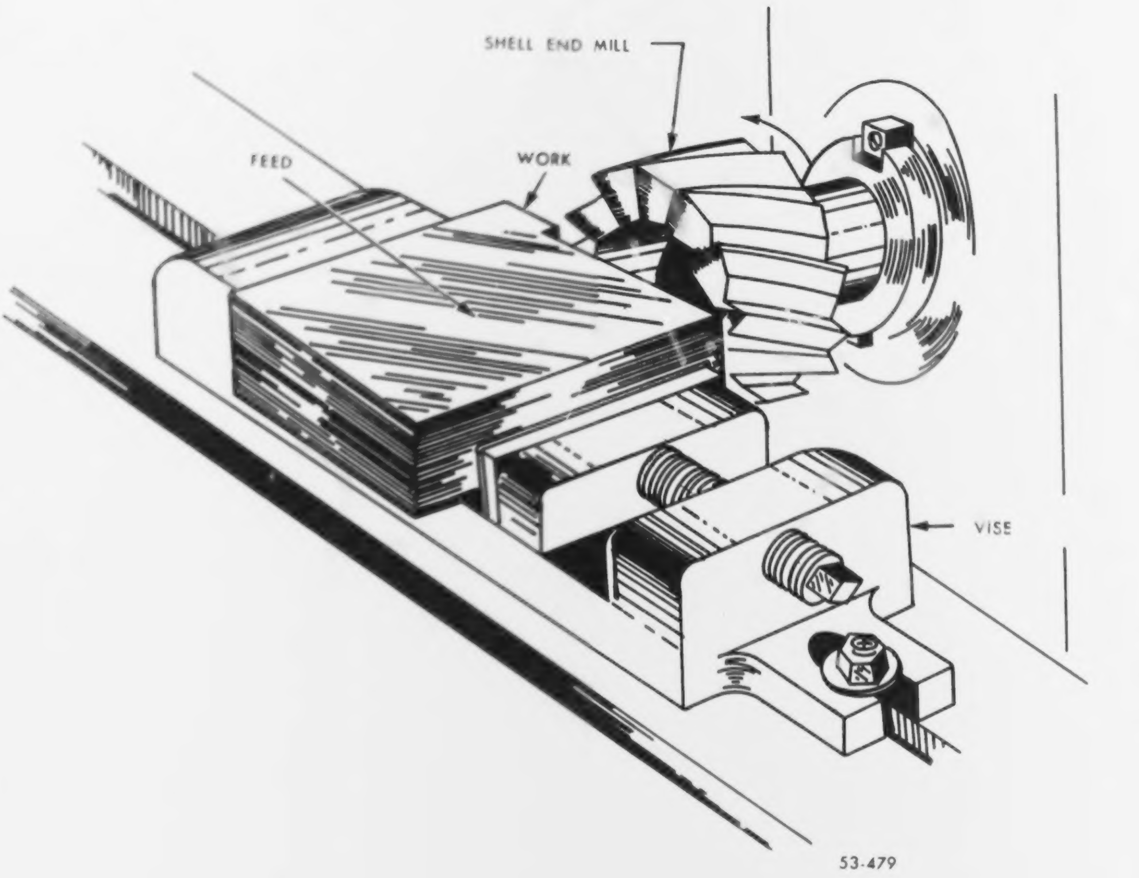


Figure 1-14. Face milling.

2. When you locate the work on a milling machine for plain milling, where should you try to position it? Why?

3. What is the purpose of face milling?

4. In face milling, what should you look for in a cutter in relation to the thickness of the work?

5. When work is held in a vise for face milling, how should the setup be made in relation to the thrust of the cutter?

404. Explain gang and angular milling operations including the setup procedures and purpose of each.

Gang Milling. In gang milling two or more cutters are mounted on the same arbor. All cutters may perform the same type of operation or each cutter may perform a different type of operation. For example, several workpieces need a slot, a flat surface, and an angular groove. The best method to cut these would be gang milling, as shown in figure 1-15. All the completed workpieces would be the same. Remember to check the cutters carefully for proper size.

Gang milling setups can save both time and labor when several identical parts must be machined on a milling machine. If you think in production terms when you receive a production-type work order, you may be able to devise cutter setups that enable you to do the necessary work with minimum time and effort.

A form of gang milling in which 2 cutters are mounted at a specified distance apart on one arbor is referred to as *straddle milling*. This type of setup is especially use-

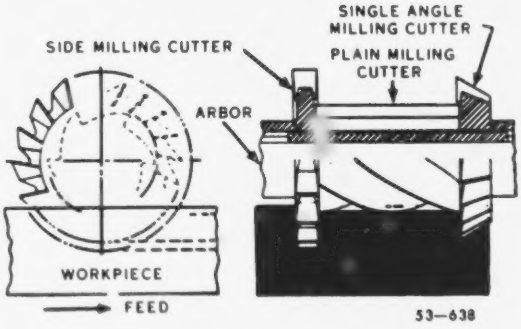


Figure 1-15. Gang milling setup.

ful for machining a square on the end of a rod or shaft, such as a tap blank. With the distance between the cutters set at the distance across the flats, one pass of the cutters will finish two sides of the square. Then, after the work is rotated 90°, the second pass will complete the other two sides. As you can see, this setup can save time, but it is sometimes difficult to find a spacer or spacers of the correct size to go between the cutters. When the correct size is not readily available, you can waste more time making one or trying to find one than if you used the single cutter method. So consider the situation carefully before you commit yourself to the type of setup.

Angular Milling. Angular milling is the milling of a flat surface that is at an angle to the cutter axis. Angular milling cutters may also be used in this operation, as shown in figure 1-16. These angular milling cutters are made to a predetermined angle, such as those made for cutting dovetails. Angular milling is done in several ways. You can do it by using the vertical head on the milling machine. Tilt the head to the required angle and use an end mill or a shell milling cutter. You can use the toolmaker's knee for angular milling operations. The toolmaker's knee affords a rapid and convenient method of setting up angular work on a milling machine.

Angular parallels are also used for angular milling. These parallels are accurately machined to a predetermined angle. With a full set, you can set them to any angle needed. Be very careful not to damage their surfaces. Always keep the vise and work clean to insure that chips do not damage the parallels.

Exercises (404):

1. What is the purpose of gang milling?

2. When you are mounting cutters for a gang milling operation, what is probably the most important consideration?

3. Explain the gang milling process called straddle milling.

4. Explain two ways of performing angular milling without setting the cutter at an angle or using angular milling cutters.

405. State the uses and characteristics of the offset boring head and fly cutters.

Offset Boring Head. Boring, an operation that is too often restricted to a lathe, can be done easily on a milling machine. On a milling machine, you can bore very accurate holes with an offset boring head. Figure 1-17 shows several views of an offset boring head and several boring tools. Note that the boring bar can be adjusted at a right angle to the spindle axis. This feature makes it possible to position the boring cutter accurately to bore holes of varying diameters. This adjustment is more convenient than adjusting the cutter in the boring bar holder or changing the boring bars. Another advantage of the offset boring head is the fact that a graduated collar allows the tool to be moved accurately a specified amount (usually in increments of 0.001) without the use of a dial indicator or other measuring device.

Never operate the boring head at the highest machine speeds because it is not balanced and therefore sets up a vibration which can produce rough finishes on the work. Also, the feed and depth of cut should be light to medium because the boring bars can spring easily and produce inaccurate hole diameters.

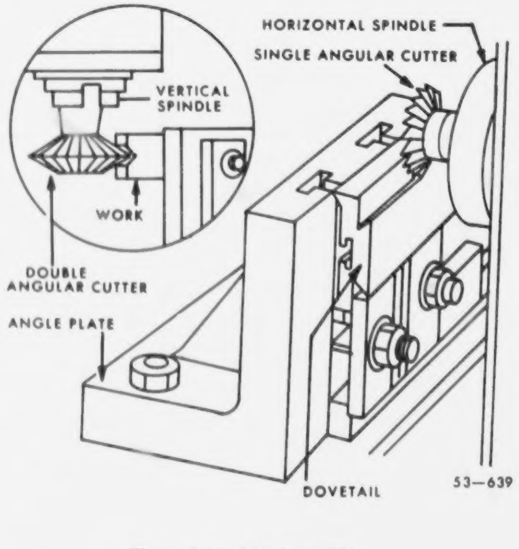


Figure 1-16. Angular milling.

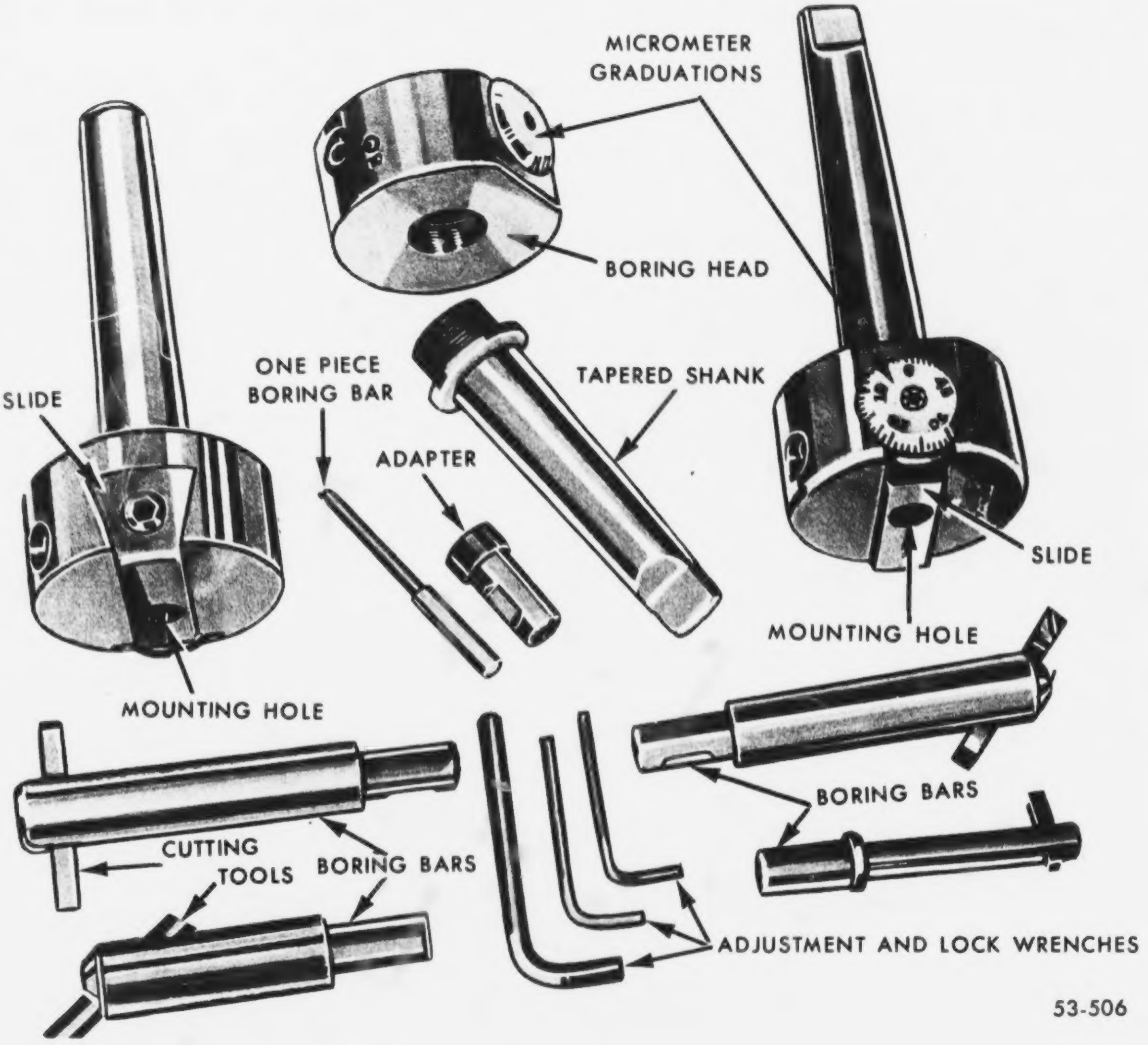

MICROMETER GRADUATIONS
BORING HEAD
ONE PIECE BORING BAR
TAPERED SHANK
SLIDE
ADAPTER
SLIDE
MOUNTING HOLE
MOUNTING HOLE
BORING BARS
CUTTING TOOLS
BORING BARS
ADJUSTMENT AND LOCK WRENCHES
53-506

Figure 1-17. Offset boring head and tools.

Fly Cutting. Fly cutting, which is also called single-point milling, is one of the most versatile milling operations. It is done with a single-point cutting tool shaped like a lathe or shaper tool. It is held and rotated by a fly cutter arbor. You can grind this cutter to almost any form that you need, as shown in figure 1-18. Formed cutters are expensive. There will be times when you need a special form cutter for a very limited number of parts. It is more economical to grind the desired form on a lathe-type tool bit than to buy a preground form cutter, which is very expensive and usually suitable only for the job at hand.

The single-point or fly cutter can be used to great advantage in gear cutting. All that you need is enough of the broken gear to grind the cutting tool to the proper shape. You can also use it in the cutting of splines and standard and special forms.

Another type of fly cutter, which differs mainly in the design of the arbor, can be used to mill flat surfaces as in plain or face milling. Figure 1-19 shows this type of fly cutter. The arbor can be easily manufactured in the shop and common lathe tool bits are used. This type of fly cutter is especially useful for milling flat surfaces on aluminum and other soft nonferrous metals, since a high-quality finish can be easily obtained. Though you can bore holes with this type of fly cutter also (provided the diameter of the hole is larger than the diameter of the arbor), it is not desirable. The arbor is so short that only very shallow holes can be bored.

Exercises (405):

1. What is the main purpose of the offset boring head?

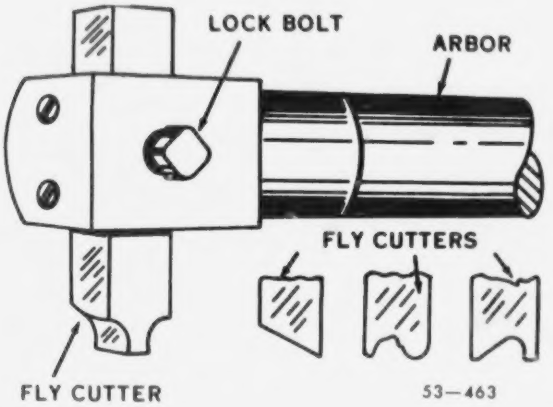


Figure 1-18. Boring-type fly cutter and arbor.

2. How is it possible to position the tool bit of an offset boring head to within 0.001 of an inch?

3. What operations can be suitably performed with fly cutters?

4. What type of cutting tools are commonly used in fly cutter arbors?

406. Evaluate the action and applications of the slotting attachment and explain the setup for a given slotting operation.

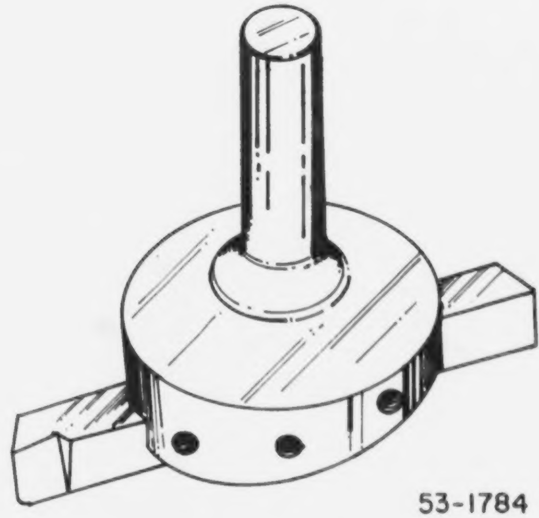


Figure 1-19. Facing-type fly cutter and arbor.

Slotting. Slotting is often regarded as a shaper operation, but it can be done on a milling machine with a slotting attachment. The slotting attachment cank perslotting attachment. *The slotting attachment can perform* internal slotting operations, such as the machining of squares, hexagons, 12-point sockets, keyseats, splines, and gear teeth, and is especially useful for tool and die work.

The slotting attachment is fastened to the milling machine column and driven by the spindle, as shown in figure 1-20. This attachment changes the rotary motion of the spindle to a reciprocating motion much like that of a shaper. You can vary the length of the stroke within a specified range. A pointer on the slotting attachment slide indicates the length of the stroke. You can pivot the head of the slotting attachment and position it at any desired angle. Graduations on the base of the slotting attachment indicate the angle at which the head is positioned. The number of strokes per minute is equal to the spindle rpm and is determined by the formula:

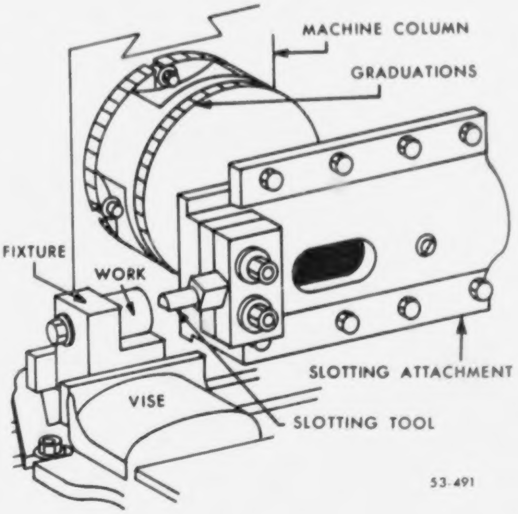


Figure 1-20. Slotting attachment.

$$\text{Strokes per minute} = \frac{\text{CFS} \times 4}{\text{length of stroke}}$$

The cutting tools that you use with slotting attachments are ground to any desired shape from high-speed steel tool blanks. These tools are then clamped to the front of the slide or ram. You can use any suitable means for holding the work, but the most common method is to hold the work in an index head chuck. If the slotted portion does not extend through the work, you will have to machine an internal recess in the work to provide clearance for the tool runout. When it is possible, position the slotting attachment and the work in the vertical position in order to provide the best possible view of the cutting action of the tool.

Slotting hexagonal shapes, or even 12-point holes for socket wrenches, is often done in Air Force machine shops. A 12-point socket is, in reality, two internal hexagons of the same size with one hexagon machined within the other. Since 12 equally spaced cuts are required, you would use the index head to space the work. Here, you can use the direct index plate to advantage. Use a hole circle equally divisible by 12. We will discuss the use of the index head in detail in a later segment of this volume.

When you mount the work in the index head chuck, align the bore of the work concentrically to insure accuracy. In a hexagon, the length of one side is equal to one-half its diagonal. Determine the diagonal of the hexagon by multiplying the distance across the flats by the constant, 1.115. Grind the width of the cutting edge of the slotting tool to equal the length of the side of the hexagon and round the back side of it to clear the bore.

You must decide in which position you want to set the slotting attachment and index head. As we stated before, it is best to hold the work vertically in the index head chuck to provide better vision. But if the work is too long to be held vertically but can be extended through the index head spindle, it can be held horizontally. In any case, the index head must be swiveled so that the position of its spindle corresponds to the position of the slotting attachment ram. A fine feed (usually by hand) is best so that the tool will not gouge or catch in the work and break the tool bit or damage the socket.

Exercises (406):

1. What type of work is the slotting attachment used for?

2. When a slotting attachment is used on a milling machine, where is it mounted and what happens to the rotating motion of the spindle as it drives the attachment?

4. How many strokes per minute should you set a slotting attachment for to cut a spline in mild steel using CFS of 80 and a 2-inch length of stroke?

5. Why is it usually better to hold the work vertically for slotting rather than horizontally?

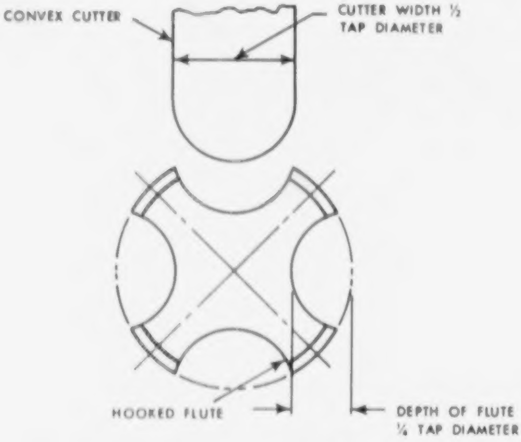
407. Analyze the calculations and procedures for setting up and cutting straight flutes on taps and reamers.

Straight Flutes. The flutes on cutting tools serve three purposes. They form the cutting edge for the tool, provide channels for receiving and discharging chips, and enable coolant to reach the cutting edges. The shape of the flute and tooth depends upon the cutter you use to machine the flute. The following information pertains specifically to taps and reamers. Since flutes are actually special purpose grooves, you can apply much of the information to grooves in general.

Tap flutes. You usually use a convex cutter to machine tap flutes. This type of cutter produces a "hooked" flute, as shown in figure 1-21. The number of flutes is determined by the diameter of the tap. Taps 1/4 inch to 1 3/4 inches in diameter usually have four flutes and taps 1 7/8 inches (and larger) in diameter usually have six flutes. The width of the convex cutter should be equal to one-half the tap diameter. The minimum length of the full depth of the flute should be equal to the length of the threaded portion of the tap. You usually mount the tap blank between centers and feed it longitudinally past the cutter. For appearance sake, the flutes are usually cut in the same plane as the sides of the square on the tap blank.

You can mill the flutes on a tap blank in the following manner. Mount and align the index centers and set the surface gage to center height. Place the tap blank between the centers with one flat of the square on the tap shank in a vertical position. You can align the flat with a square head and blade. Scribe a line on the tap shank.

Remove the tap blank, place a dog on the shank, and remount the blank between centers. Then align the scribed line with the point of the surface gage scriber. Make sure that the surface gage is still at



53-504

Figure 1-21. Hooked tap flutes.

center height. Mount the convex cutter. Make sure that the direction of the cutter rotation is correct for conventional (or up) milling and that the thrust is *toward* the index head. Align the center of the cutter with the axis of the tap blank. Pick up the surface of the tap. Set the table trip dogs for the correct length of cut and set the machine for roughing speed and feed.

Rough mill all flutes to within 0.015 inch to 0.020 inch of the correct depth. Set the machine for finishing speed and feed and finish machine all flutes to the correct size. Remove the work, deburr, and check it for accuracy.

Reamer flutes. Flutes can be milled on reamers with angular cutters, but you normally use special formed fluting cutters. The advantages of the formed flute compared to the flute milled with an angular cutter are that the chips are more easily removed and the cutting tooth is stronger. Also, the tooth is less likely to crack or warp during heat treatment. Formed reamer fluting cutters have a 6° angle on one side and a radius on the other side, its size depending upon the size of the cutter. Reamer fluting cutters are manufactured in eight sizes, with the size of the cutter identified by a number (1 through 8). Reamers from 1/8 inch to 3 inches in diameter are fluted by the eight cutter sizes given in figure 1-22. You machine reamer teeth with a slightly negative rake to prevent chatter. You obtain the negative rake by positioning the work and cutter slightly ahead of the reamer center, as shown in figure 1-23. Figure 1-24 lists the recommended offset for reamers of various sizes. Straight reamer flutes are usually unequally spaced to help prevent chatter. You obtain the unequal spacing by indexing the required amount as each flute is cut. The recommended variation is approximately 2°. Machinists' publications, such as the *Machinery's Handbook,* contain charts that list the number of holes to advance or retard the index crank to machine a given number of flutes when you use a given hole circle. You usually mill the flutes in pairs. After you have machined one flute, index the work one-half revolution and mill the opposite flute.

The depth of the flute is determined by trial and error. The approximate depth to obtain the recommended width of land is one-eighth the diameter for an eight-fluted reamer, one-sixth the diameter for a six-fluted reamer, etc.

You can machine the flutes on a hand reamer in the following way. Mount the reamer blank between centers and the reamer fluting cutter on the arbor. Align the point of the cutter with the reamer blank's axis and just touch the surface of the reamer with the rotating cutter. Remove the work blank, and then raise the table a distance equal to the depth of the flute plus one-half the grinding allowance. Rotate the cutter until a tooth is in the vertical position. Then shut off the machine.

Move the table until the point of the footstock center is aligned with the tooth that is in the vertical position. Place an edge of a 3-inch rule against the 6° surface of the reamer tooth. Move the saddle until the edge of the 3-inch rule that is touching the cutter tooth is aligned with the point of the footstock center. In order to eliminate backlash, move the saddle in the same direction it will move when you offset the cutter. Continue feeding the saddle until you obtain the desired amount of offset, then lock it in position. Move the table until the cutter clears the end of the reamer blank. Then remount the blank between the centers. Calculate the indexing required to space the flutes unequally. Set the table feed trip dogs so that the minimum length of the full depth of flute is equal to the length of the reamer teeth. Rough machine all flutes.

NOTE: Write down the exact indexing that you used for each of the flutes to avoid confusion when you index for the finish cut.

If a form cutter is not available, you can use a fly cutter. The flutes of another reamer can be used as a gage for checking the form of fly cutter as you grind it.

Exercises (407):

1. You are preparing to cut flutes in a tap blank to make a 2-inch diameter tap. How many flutes should you cut?

Cutter number	Reamer diameter (inches)	Number of reamer flutes
1	1/8 to 3/16	6
2	1/4 to 5/16	6
3	3/8 to 7/16	6
4	1/2 to 11/16	6 to 8
5	3/4 to 1	8
6	1 1/16 to 1 1/2	10
7	1 9/16 to 2 1/8	12
8	2 1/4 to 3	14

53-498

Figure 1-22. Reamer fluting cutter numbers.

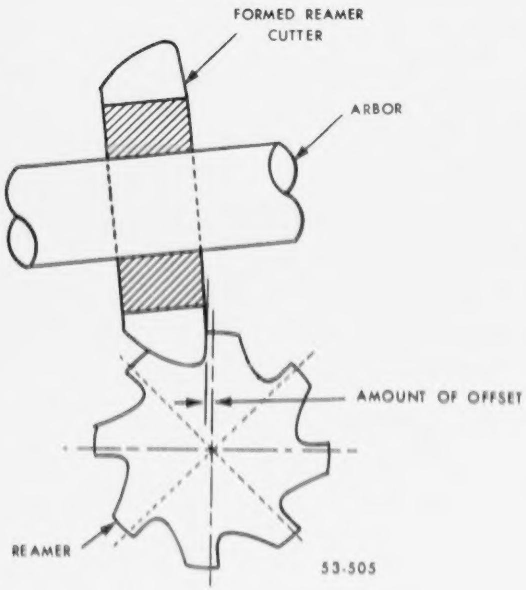


Figure 1-23. Negative rake tooth.

2. In the problem given in question 1, how wide should the convex cutter be and how deep should the flutes be machined?

3. What type of cutter is normally used to mill flutes on a straight reamer?

4. What reamer sizes can be cut with a number 5 fluting cutter? How many flutes are required for these reamers?

5. What is the recommended variation (in degrees) in the spacing that should be cut in a reamer?

6. If a reamer fluting cutter is not available, what method can be used to machine the flutes?

408. Explain the calculations and the procedures for machining external keyseats, and calculate the micrometer reading in a given situation.

External Keyseat. Machining an external keyseat on a milling machine is less complicated than machining it on a shaper. In milling, starting an external keyseat is no problem. You simply bring the work in contact with a rotating cutter and start cutting. It should not be too difficult for you to picture in your mind how you should mill a straight external keyseat with a plain milling cutter or an end mill. If the specified length of the keyseat exceeds the length you can obtain by milling to the desired depth, you can move the work in the direction of the slot to obtain the desired length. Picturing in your mind how you would mill a Woodruff keyseat should be easier. The secret is to select a cutter with the same diameter and thickness as the key.

Straight external keyseats. Normally, you would use a plain milling cutter to mill a straight external keyseat. You could use a Woodruff cutter or a two-lipped end mill. A two-lipped end mill is specified because, with it, you can usually cut a keyseat in the middle of a shaft without drilling a starting hole. End mills with more flutes require a starting hole.

Before you can begin milling the keyseat, you must align the axis of the work with the midpoint of the width of the cutter. Suppose that you are going to cut a keyseat with a plain milling cutter. Move the work until the side of the cutter is tangent to the circumference of the work. With the cutter turning very slowly and before making contact, insert a piece of paper (cellophane is better if available) between the work and the side of the cutter. Continue moving the work toward the cutter until the paper begins to tear. When it does, lock the graduated dial at ZERO on the saddle feed screw. Then lower the milling machine knee. Using the saddle feed dial as a guide, move the work a distance equal to the radius of the work plus one-half the width of the cutter. This method works just as well when an end mill or a Woodruff center is used.

Size of reamer (inches)	Offset of cutter (inches)
1/4	0.011
3/8	0.016
1/2	0.022
5/8	0.027
3/4	0.033
7/8	0.038
1	0.044
1 1/4	0.055
1 1/2	0.066
1 3/4	0.076
2	0.087
2 1/4	0.098
2 1/2	0.109
2 3/4	0.120
3	0.131

53-499

Figure 1-24. Required offset.

Specifications for the depth of cut are usually furnished. When specifications are not available, you can determine the total depth of cut for a square keyseat by the following formula and the dimensions in figure 1-25:

$$\text{Total depth of cut (T)} = d + f,$$

where

$$d = \frac{W}{2} = \text{depth of keyseat}$$

$$f = R - \sqrt{R^2 - \left(\frac{W}{2}\right)^2} = \text{height of arc}$$

W = width of key

R = radius of shaft

The height of arc (f) for various sizes of shafts and keys can be obtained from a machinist's publication such as the *Machinery's Handbook*. Keyseats may be checked for accuracy with rules, outside and depth micrometers, vernier calipers, and go-no-go gages.

Woodruff keyseat. A Woodruff keyseat is a small half-disc of metal. The rounded portion of the key fits in the slot in the shaft. The upper portion fits into a slot in a mating part, such as a pulley or gear. Align the work with the cutter and measure the width of the cut in exactly the same way as for milling straight external keyseats.

A Woodruff keyseat cutter has deep flutes cut across the cylindrical surface of the teeth. Figure 1-6 shows a Woodruff keyseat cutter. The cutter is slightly thicker at the crest of the teeth than it is at the center, providing clearance between the sides of the slot and the cutter. There is a hole in the center of 2-inch-diameter and larger cutters for arbor mounting. On smaller cutters, the cutter and the shank are one piece. Note that the shank is "necked in" back of the cutting head to provide additional clearance.

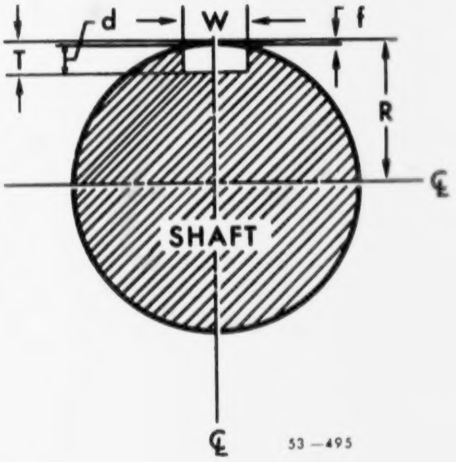


Figure 1-25. Keyseat dimensions for straight square key.

Cutting a Woodruff keyseat is relatively simple since the proper sized cutter has the same diameter and thickness as the key. You simply move the work up into the cutter until you obtain the desired keyseat depth. The work may be held in a vise, chuck, between centers, or clamped to the milling machine table. Depending on its size, the cutter is held on an arbor, or in a spring collet or drill chuck that has been mounted in the spindle of the milling machine.

The cutter can be positioned over the work in the same way as for straight keyseats, as described above. If specifications for the total depth of cut are not available, the correct value may be determined by the following formula:

$$\text{Total depth (T)} = d + f$$

where

f = height of arc (computed the same as for straight keyseats)
d (depth of the keyseat) = H - W/2
H = total height of the key
W = width of the key

The most accurate way to check the depth of a Woodruff keyseat is to insert a Woodruff key of the correct size in the keyseat. Measure over the key and work with an outside micrometer to obtain the distance M in figure 1-26. The correct micrometer reading for measuring over the shaft and key can be determined by the formula:

$$M = D + \frac{(W)}{(2)} - f$$

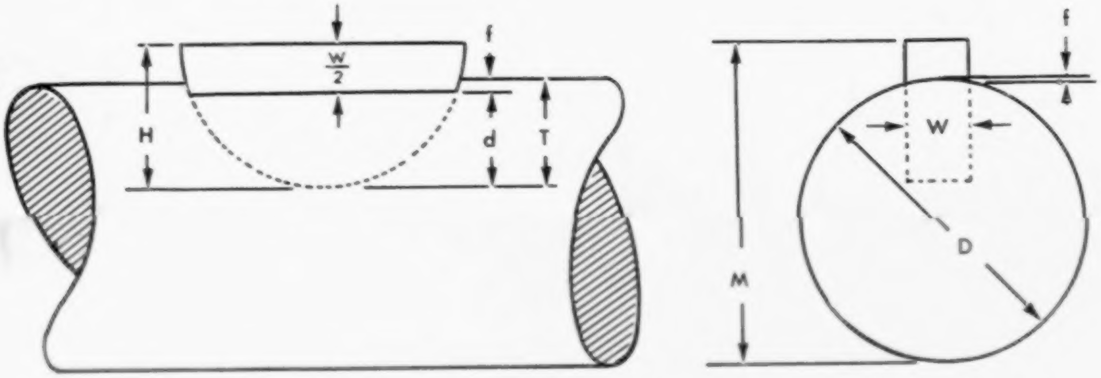
where

M = micrometer reading.
D = diameter of shaft.
W = width of key.
f = height of arc.

NOTE: Tables in some references may differ slightly from the above calculation for the value M because of the greater allowance for clearance at the top of the key.

Exercises (408):

1. You must cut a 2-inch long keyseat, .6 inches from the end of a 2-foot long shaft, and you do not have a plain milling cutter of the right width. What other cutters could you use?



53—503

Figure 1-26. Dimensions for Woodruff keyseat.

2. After you have picked up the side of the shaft with the side of the cutter and have lowered the table, how far should you move the table in order to center the cutter over the work for milling a keyseat?

3. What two dimensions must you consider when you are calculating the total depth of cut for a straight external keyseat?

4. What should the depth of the keyseat be for a 1/4-inch-wide key?

5. How should you mount a 2 1/8 inch Woodruff keyseat cutter in a milling machine?

6. What is the micrometer reading over the Woodruff key and the shaft when the shaft measures 1 inch, the key width is 1/4 inch, and the height of the arc is 0.0159?

409. Describe indexing, and make indexing calculations.

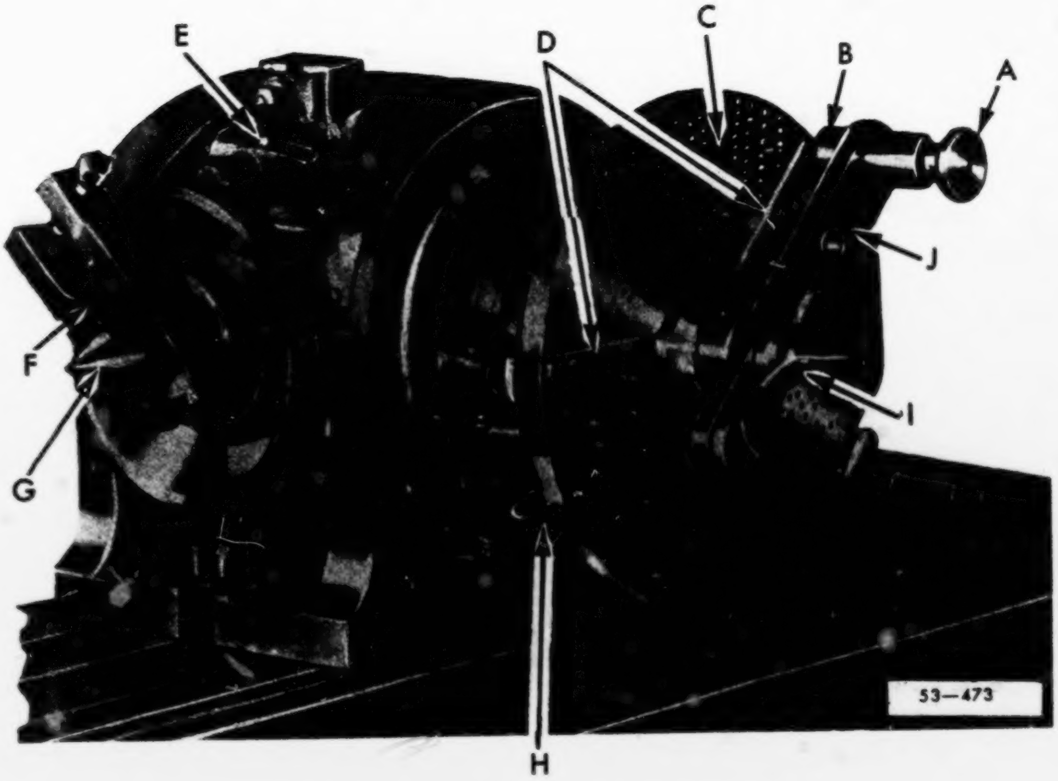
As you know, indexing is the process that you use to divide the circumference of a workpiece into a desired number of divisions. Indexing is usually done on an indexing head, frequently called a dividing head. Although there are several makes, they are all similar. Figure 1-27 shows a typical index head and lists the main parts.

Types of Indexing. Direct, plain, and degree indexing are the methods of indexing that you may use. The method you select depends upon the number of divisions required and the method that you use to measure the spacing between the divisions. The following information will help you understand when to use and how to perform the various types of indexing.

Direct. Direct indexing is the simplest means of dividing a workpiece into a required number of equal divisions. Simply rotate the work until the correct hole is aligned with the index pin. The direct index plate is usually located directly behind the chuck or is a part of the spindle. A special index pin is used for direct indexing, and you do not use the index pin on the crank. On most index heads, there is a provision for disengaging the worm and worm wheel so that you can rotate the work and spindle by hand. You can use a plate with 24 evenly spaced holes to index any number of divisions that can be divided evenly into 24; for example, 2, 3, 4, 6, 8, etc. For example, if you desire to machine a hexagonal head on a bolt, divide the number of holes on the index plate (24) by the required number of divisions (6). Therefore, you must rotate the work four holes for each of the six sides.

NOTE: *Do not* count the hole that the pin is in when you begin counting.

Plain. Use plain indexing when you cannot obtain the required number of divisions by direct indexing. In plain indexing, you rotate the work by turning the index crank. The radio between the crank and the spindle is usually 40 to 1, although many index heads are produced with a 50 to 1 ratio. We will discuss the 40 to 1 ratio because it is still the most common type in the Air Force. The 40 to 1 ratio means that the work rotates 1/40 of a turn for each full turn of the index crank. Stated another way, it requires 40 turns of the index crank to rotate the work one complete revolution. Therefore, to determine the number of revolutions of the index crank, you must divide 40 by the number of divisions you need. For example, to divide the work into 2 divisions, you would rotate the index crank 20 full turns; and to obtain 4 divisions, 10 full



A Plunger
B Index pin
C Index plate
D Sector arms
E Direct index pin lever
F Drive plate
G Center
H Slide plate stop
I Locknut
J Crank

Figure 1-27. Universal index head.

turns, etc. Rings of holes, called hole circles, are used when the index crank must rotate a portion of a turn. If a fraction remains after you have divided 40 by the number of divisions desired, the numerator indicates the number of holes in the hole circle. Suppose that you are making a special bolt for an aircraft part and are ready to mill the hexagonal head. How many turns of the index crank are required to place each of the six sides in the proper position?

$$40 \div 6 = 6\ 4/6 \text{ turns}$$

You would move the index crank 4/6 of a turn by moving it 4 holes in a 6-hole circle, if you have an index plate that has a 6-hole circle. Normally, you will not have such a plate. Therefore, you must change the fraction to an equivalent fraction with a denominator equal to an available hole circle. If a 24-hole circle is available, you could obtain the 4/6 turn by moving the index crank 16 holes in the 24-hole circle, since:

$$4/6 = 16/24$$

Therefore, to mill the hexagonal bolt head, you would turn the index crank 6 full turns and 16 holes in a 24-hole circle for each of the six sides.

Do not change the index plate until you have checked to make sure that none of the hole circles on the mounted index plate are suitable for your use. For example, your calculations may indicate that you must move the index crank 3 holes in an 18-hole circle. Perhaps the mounted plate has a 36-hole or a 54-hole circle that you could use and not have to expend time and effort changing the plate. The sector arms, shown in figure 1-27, are time-saving devices that eliminate the need for counting the holes for each division. You adjust the sector arms so that the index pin and the required number of holes are located between their beveled sides. Lock the arms at the desired setting by tightening the setscrew located at the base of the sector arms near the crank spindle. Then position the section formed by these arms by moving it in the direction of the index crank rotation until one sector arm contacts the index pin. After you have turned the index crank the required number of full turns, continue turning the index crank until the index pin is positioned next to the other sector arm.

Degree. Degree indexing is indexing when the spacing between holes or surfaces is in degrees rather than in divisions. You can use direct indexing when the number of degrees you need can be divided into 360° and when the quotient you obtain can be divided evenly into the number of holes on the direct indexing plate. For example, to divide the work into 30° divisions, divide 360° by 30. The quotient 12 indicates that you must divide the work into 12 divisions that are 30° apart. Now divide 24 (the number of holes on the direct index plate) by 12 (the number of divisions). The quotient (2) indicates the number of holes that you use to index 30° on the direct index plate.

When you must divide the work into degrees by plain indexing, remember that one turn of the index crank rotates the work 1/40 of a revolution. Since 1 revolution of the work equals 360°, one turn of the index crank revolves the work 1/40 of 360°, or 9°. Therefore, 1/9 of a turn of the index crank revolves or indexes the work 1°. When you select the dividing head index plate for degree indexing a workpiece, 2 holes in an 18-hole circle index the work 1°; 1 hole in a 27-hole circle indexes 1/3°; 6 holes in a 54-hole circle indexes 1°; 3 holes in a 54-hole circle indexes 1/2°; and 2 holes in a 54-hole circle indexes 1/3°. To determine the number of turns and parts of a turn of the index crank needed to index the work for the desired number of degrees, divide the number of degrees to be indexed by 9. The quotient represents the number of complete turns and fraction of a turn that the index crank should rotate. The sector arms are set for the number of holes that give the desired fraction of a turn. The calculation for indexing work 15° using an index plate with a 54-hole circle is as follows:

$$15/9 = 1\ 6/9 = 1\ 36/54$$

or one complete turn of the index crank and 36 holes in a 54-hole circle. The calculation for indexing work 13 1/2° using the 18-hole circle of an index plate is as follows:

$$\frac{13\ 1/2}{9} \times \frac{2}{2} = 27/18 = 1\ 9/18$$

or 1 complete turn and 9 holes in an 18-hole circle. We multiplied both parts of the fraction by 2 to get rid of the fraction in the numerator. If the fraction had been 1/3, we would have multiplied both numerator and denominator by 3; etc.

Wide range. You use wide range indexing to obtain divisions that you cannot obtain by using simpler indexing methods. A wide range index head has two index plates and two index cranks. The small index crank is geared so that 160 revolutions is equal to 1 revolution of the large index crank. It requres 40 revolutions of the large index crank to rotate the work one full turn; therefore, one complete turn of the large crank equals 40 divisions. If a 100-hole circle is used, 1 hole on the large index plate equals $\frac{1}{4,000}$ revolution.

You determine the number of turns of the large and small index cranks by dividing 400,000 by the number of divisions desired. The first two digits of the quotient indicate the number of holes on the large index plate and the next two digits equal the number of holes on the small index plate, if you are using 100-hole circles for both of them. If fewer than 40 divisions are indexed, a five-digit quotient will result. The first digit of a five-digit quotient equals the number of full revolutions of the large index crank. If a fraction remains after the division, divide 1 by the fraction and add one hole to the indexing movement of the small crank at intervals equal to the whole number nearest the result of the division. You will not be able to compensate entirely for the remaining fraction, but the error resulting from one hole on a 100-hole circle on the small index plate is only 0.0000942 inch on a 12-inch diameter. The following example will help you understand how to perform wide range indexing. How would you index 67 divisions, using wide range indexing?

Dividing 400,000 by 67 gives 5,970 10/67. Set the sector on the large index plate to obtain 59 spaces on the 100-hole circle and the sector on the small index plate to obtain 70 holes on the 100-hole circle. For each division, move the large index crank 59 holes and the small index crank 70 holes in the same direction. Compensate for the fraction (10/67) by adding 1 hole on the small index plate every 7th division, since the nearest whole number that you obtain by dividing 1 by 10/67 is 7.

Compound. When a wide range index head is not available, a method called compound indexing can be used on a plain index head to obtain a wider range of divisions. In compound indexing, the crank is moved a specific number of holes in one direction on a certain hole circle and the index *plate* is then revolved a specific number of holes using another hole circle and in the *opposite* direction. For example, to obtain 69 divisions, you would rotate the crank 21 holes in a 23 hole circle and then rotate the index plate 11 holes in the opposite direction in a 33 hole circle. Machinists' publications such as the *Machinery's Handbook*, contain instructions for calculating for compound indexing and also contain tables giving the required movements for indexing many divisions that are beyond the range of those that can be obtained by the simple indexing method.

Exercises (409):

1. How is the work normally rotated when you perform direct indexing on the index head?

2. Using plain indexing, how many turns and holes should the crank be turned to index 16 divisions using an 18 hole circle on the index plate?

3. What enables you to index any number of holes on the index plate without actually counting them each time?

4. Briefly describe degree indexing.

5. If the *direct* index plate is moved 4 holes on a 24-hole circle, how many degrees does the plate revolve?

6. How many degrees will the work revolve if the index crank is turned 19 complete turns?

7. If a 27-hole circle is available, how many turns and holes are required to index 28 1/3°?

8. How does a wide range index head differ from a plain index head?

9. How many holes should the large and small index cranks be moved to index 108 divisions using the wide range indexing head with 100 hole circles for both large and small index cranks?

10. How does compound indexing differ from plain indexing?

410. Explain key procedures for milling graduations, and compute the turns required in a specific graduation problem.

Milling Graduations. Milling graduations is the process of spacing and cutting divisions on linear or circular work. Graduating can be done on a milling machine with a stationary sharp-pointed tool that scribes the graduations on the work. Another method is to mill the graduations with an angular cutter. The latter method produces a smoother line because there is less chance for the cutter to burr the work.

Linear graduations. Linear graduating is spacing and cutting divisions in a linear plane or straight line, such as the graduations on a rule, vernier caliper, or height gage. If extreme accuracy is not required, you can do linear graduating on a milling machine by

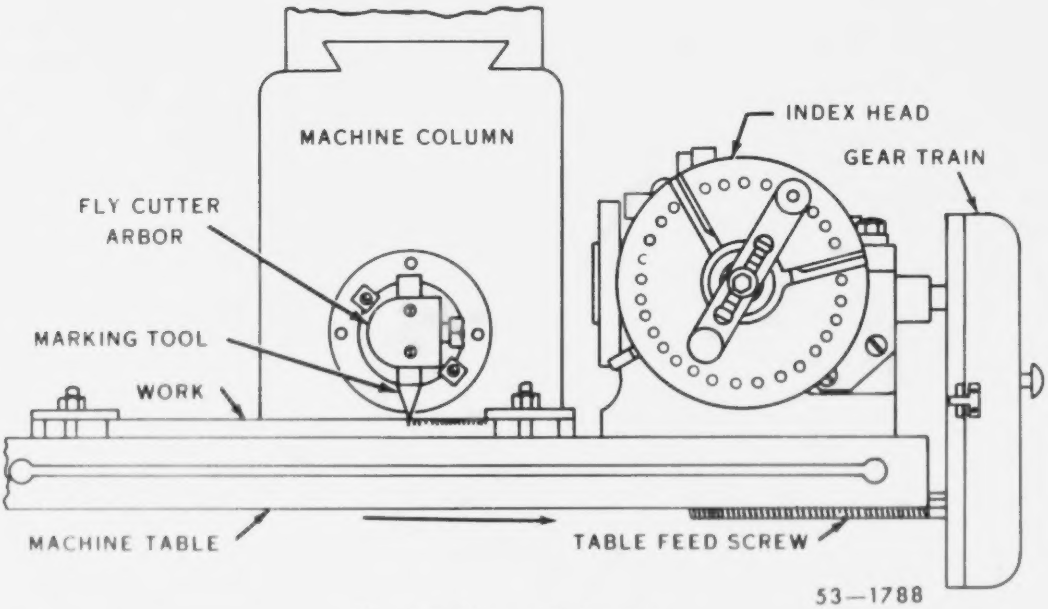


Figure 1-28. Linear graduation setup.

moving the table longitudinally, using the feed screw dial. A more accurate method of linear graduating is to gear the index head to the table feed screw, as shown in figure 1-28. You rotate the index head crank to cause the table and work to advance the required distance for each division.

You must consider several factors when you calculate the change gears to use for the index head. The ratio between the worm shaft and the index head spindle is 40:1. The table feed screw has a lead of 0.250 inch. Therefore, if you gear the table feed screw directly to the index head spindle with gears having a 1 to 1 ratio and you turn the index head crank one revolution, the table will advance 1/40 of 0.250 inch, or 0.00625 inch. To advance the table 1/64 inch, 2½ turns on the crank would be required (2½ × 0.00625 = 0.015625 inch, or 1/64 inch). Five turns advance the table 1/43 inch, 10 turns 1/16 inch, 20 turns 1/8 inch, 40 turns 1/4 inch, etc. Thus, you can cut all standard fractional divisions with a 1 to 1 gear ratio between the index head spindle and the table feed screw. By calculating gear ratios and indexing, you can work out various ranges of division. We will discuss the calculations for change gears in more detail in Section 1-4 of this chapter.

Circular graduations. Circular graduations consists of spacing and cutting graduations on circular work, such as a feed screw dial, a protractor head, or the thimble of a micrometer. You can do circular graduating by mounting the work in the index head. The graduations may be scribed on the work with a single-pointed graduating tool held stationary on the work. Use the longitudinal feed to feed the work under the cutter to produce graduation lines of the desired length. It is best to do the feeding by hand on this type of work.

Exercises (410):

1. When great accuracy is not required, what method can be used to produce linear graduations?

2. What method should be used to produce linear graduations when great accuracy is required?

3. Using a 40 to 1 ratio index head, a milling machine with 0.250 inch feed screw, and 1 to 1 gears from the table to the index head, how many turns would be required to move the work 5/64 inch?

4. What are the two types of cutters commonly used for milling circular graduations?

5. How is the work supported and moved to produce circular graduations?

1-3. Milling Machine Attachments

Many attachments have been developed that increase the number of jobs a milling machine can do or that make such jobs easier to do. By using a universal milling attachment, you can swivel the cutter to any position in both the vertical and horizontal planes. By using a high-speed attachment, you can perform milling operations at higher speeds than those for which the machine was designed. These attachments make complex jobs easier.

411. Describe the purpose and characteristics of selected milling machine attachments.

High-Speed Universal Attachment. This device is clamped to the machine and is driven by the milling machine spindle, as you can see in figure 1-29. The attachment spindle head and cutter can be swiveled 360° in both planes. The attachment spindle is driven at a higher speed than the machine spindle. You must consider the ratio between the rpm of the two spindles when you calculate cutter speed. Small cutters, end mills, and drills should be driven at a high rate of speed to obtain an efficient cutting action.

Circular Milling Attachment. This device, shown in figure 1-30, is a circular table which is mounted on the

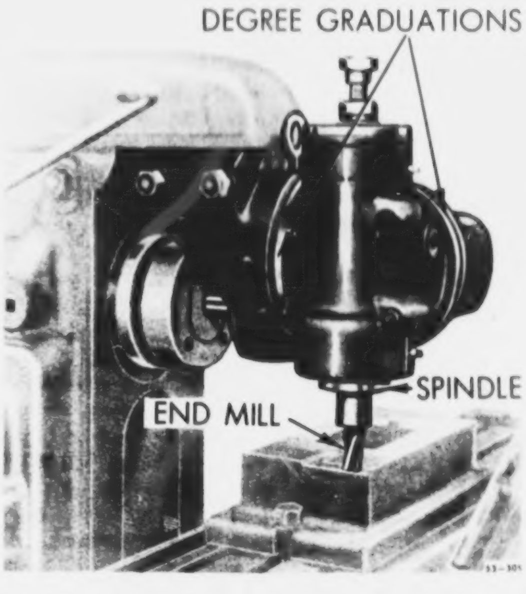


Figure 1-29. High-speed universal milling attachment.

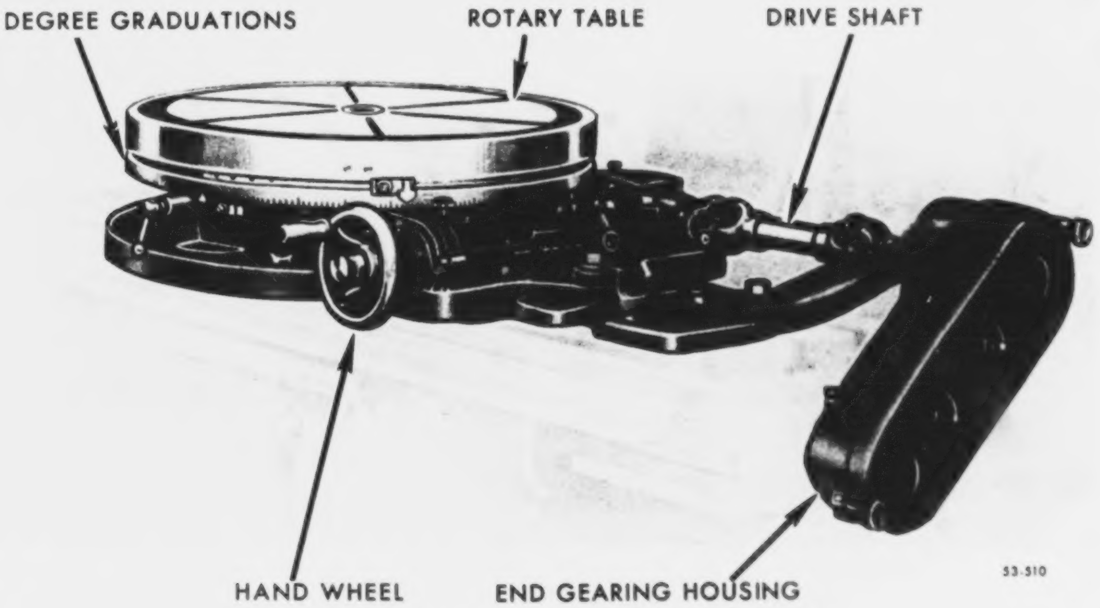


Figure 1-30. Circular milling attachment.

milling machine table. The circumference of the table is graduated in degrees. Smaller attachments are usually equipped for hand feed only and larger ones are equipped for both hand and power feed. The work is mounted on the circular table. This attachment is used for milling circles, arcs, segments, circular T-slots, and internal and external gears. It may also be used for irregular form milling.

Rack Milling Attachment. The rack milling attachment, shown in figure 1-31, is used primarily for cutting teeth on racks, although it can be used for other operations. The cutter is mounted on a spindle that extends through the attachment parallel to the table T-slots. Therefore the cutter is aligned to cut across the table (transversely) instead of lengthwise (longitudinally). This allows longer racks to be milled. An indexing arrangement with the index head geared to the table is used to space the rack teeth quickly and accurately.

Right-Angle Plate. The right-angle plate, shown in figure 1-32, is attached to the table. With the right-angle slot you can mount the index head so that the axis of the head is parallel to the milling machine spindle. With this attachment you can make work setups that are off center or at a right angle to the ups that are off center or at a right angle to the table T-slots. The standard size plate T-slots make it convenient to change from one setting to another for milling a surface at a right angle.

Raising Blocks. Raising blocks, shown in figure 1-33, are heavy-duty parallels, which usually come in matched pairs. They are mounted on the table and the index head is mounted on the blocks. This arrangement raises the index head and makes it possible to swing the head through a greater range to mill larger work.

Toolmaker's Knee. The toolmaker's knee, shown in figure 1-34, is a simple but useful attachment for setting up angular work, not only for milling but for

SPINDLE
WORK HOLDING FIXTURE
53-111

Figure 1-31. Rack milling attachment.

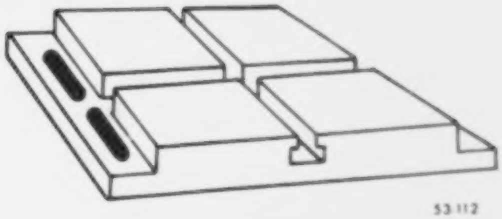


Figure 1-32. Right-angle plate.

shaper, drill press, and grinder operations as well. You mount a toolmaker's knee, which may have either a stationary or rotatable base, to the table of the milling machine. The base of the rotatable type is graduated in degrees, enabling you to machine compound angles. The toolmaker's knee has a tilting table with either a built-in protractor head graduated in degrees for setting the table or a vernier scale for more accurate settings.

Slotting Attachments. As we stated previously in segment 406, you can perform internal slotting operations, such as the machining of squares or hexagons, sockets, keyways, splines, internal gears, and various other shapes, with a slotting attachment. The slotting attachment is fastened to the milling machine column and driven by the spindle. A bull wheel and arm change the rotary motion of the spindle to a reciprocating motion. The length of stroke can be varied and attachment can be pivoted around the spindle to any desired angle.

Exercises (411):

1. If you had to mill several curved surfaces at various angles on a job that must be clamped to the attachment, what two attachments would best suit the job?

2. How does the poisition of the cutter differ from its usual position when the rack milling cutter is used?

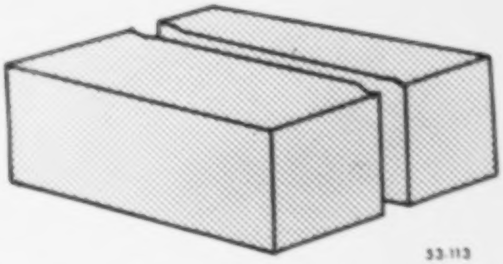


Figure 1-33. Raising block.

3. What two attachments are designed primarily for increasing the capabilities of the index head? Explain.

4. What is the purpose of the toolmaker's knee and how does it work?

5. In the slotting attachment, what is the purpose of the bull wheel and arm?

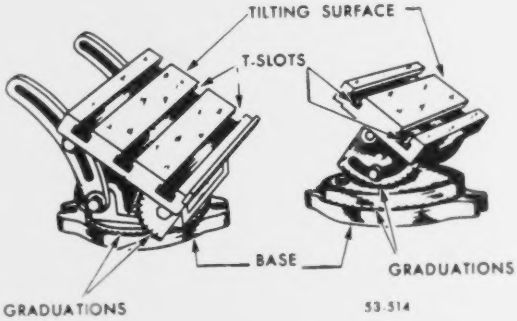


Figure 1-34. Toolmaker's knee.

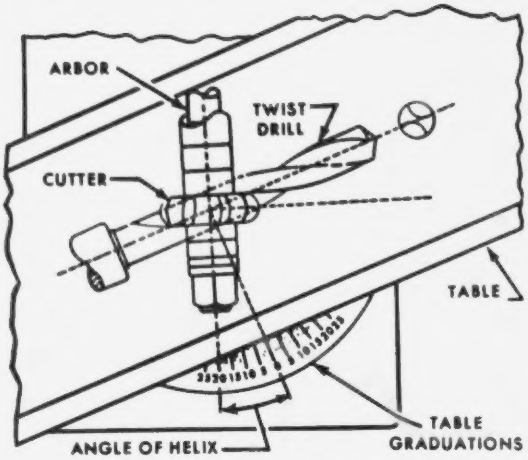
1-4. Gear Cutting and Calculations

An important operation that is performed on the milling machine is gear cutting. You may be required to cut several different types of gears, such as spur gears, helical gears, and bevel gears. In this section, we will discuss the procedure for milling a helix and for machining bevel gears. The procedure for milling a helix can be applied to the milling of helical gears as well as reamers, drill bits, etc. Spur gear cutting is covered at length in CDC 53130, Volume 4.

412. Point out some of the procedures for milling a helix and calculate given helix milling problems.

Helical Milling. A helix is a curve or path formed by the progressive rotation of a point around the surface of a cone or cylinder, such as the thread of a screw. You form a helix on the milling machine by causing the work to rotate while it is fed longitudinally to the cutter. The work rotates because the table feed screw is geared to the index head. As the table feed screw revolves, the work revolves while it is fed to the cutter in a line parallel with its axis, as shown in figure 1-35.

Helical work includes the milling of helical tooth milling cutters, helical reamers, twist drills, helical gears, some types of cams, etc. Milling a helix is similar to cutting a thread on the lathe. In cutting a thread, the tool moves a certain distance while the work makes



53—1786

Figure 1-35. Helical fluting setup.

one revolution. This distance is the lead of the thread and is governed by the gear ratio between the lathe spindle and its feed screw. This is also true in milling a helix. In milling, the distance it must feed in order to revolve once is termed the lead of a helix. The lead of a thread is usually short in proportion to its diameter and length while the lead of a helix can be long in proportion to its diameter and length.

For example, a 1-inch single threaded screw with 8 threads per inch has a ⅛-inch lead, but the lead of a helix on a 1-inch reamer may be as much as 18 inches. The helix may make several turns around the work or it may make only a fraction of a turn around the work and still have the same lead, depending upon the length of the helix. For instance, on a reamer flute 6 inches in length with an 18-inch lead, the helix makes only one-third of a turn around the piece. If the piece were 18 inches in length and had a helix with an 18-inch lead, the helix would make a complete turn around the work. In both cases the lead is the same. A helix can be either right hand or left hand, like the threads on a screw. A right-hand helix runs off to the right as it is viewed from the end. A left-hand helix runs off to the left.

The lead of a helix is the distance the helix advances in one complete turn around the work, measured on a line parallel with the axis of the work. If the gearing between the table feed screw and the index worm were such as to cause the index spindle to revolve once as the table is fed 10 inches, then the lead would be 10 inches. The length of the work or the length of the cut makes no difference. To find the lead of a helix, multiply the diameter of the helix by 3.1416 and divide the product by the tangent of the helix angle:

$$\frac{D \times 3.1416}{\text{Tan of helix angle}} = \text{lead}$$

Example: A piece ¾ inch in diameter is to have a helix whose angle is 11°7'. What is its lead?

$$\frac{.750 \times 3.1416}{.19649} = 12 \text{ inch lead}$$

The lead of the helix is expressed in inches, as 6-inch lead, 14-inch lead, 2.5-inch lead, etc.

The angle of the helix is the angle formed by a line tangent to the side of the helix and a line parallel with the axis of the helix. The helix may be represented by a right angled triangle, as shown in figure 1-36. The base of the triangle represents the circumference of the cylinder. The vertical leg of the triangle represents the lead of the helix, and the hypotenuse of the triangle represents the length of the helical path. The angle of the helix is the angle formed by the vertical leg and the hypotenuse of the triangle. The tangent of the angle of helix may be found by multiplying the diameter of the cylinder by 3.1416 and dividing this produce by the lead of the helix:

$$\text{Tan of helix angle} = \frac{D \times 3.1416}{\text{lead}}$$

Example: Find the angle of a helix whose diameter is 3/4 inch with a lead of 12 inches:

$$\frac{.750 \times 3.1416}{12} = .19635 = 11°7'$$

Therefore, the table of the milling machine would have to be swiveled to an angle of 11°7' to cut the required helix.

After swiveling the table, you must select the gears for the index head and the feed screw that will provide the proper ratio. Since the lead of the helix is 12 and the lead of the table is 10, the ratio is 12 to 10. If these gears are available, it is a simple matter to connect them and mill the helix, but since a 10-tooth gear is not usually furnished with a milling machine, you must compound the gearing. Compound gearing uses two driving gears to produce the same ratio that would be produced if you could use one driving and one driven gear. To compound the gearing, you must factor the original ratio. The factors of 10 and 12 are 5 × 2 and 4 × 3, or:

$$\frac{10}{12} = \frac{5 \times 2}{4 \times 3}$$

The factors of the lead of the machine (10) are the driving gears and the factors of the lead of the helix (12) are the driven gears. Since you do not have gears with the number of teeth indicated (5 and 2, and 4 and 3), you must multiply both of the terms of the factors by a number that will result in a number of teeth that are available. Thus:

$$\frac{5}{4} \times \frac{8}{8} = \frac{40 \text{ driving (first)}}{32 \text{ driven (last)}}$$

and

$$\frac{2}{3} \times \frac{16}{16} = \frac{32 \text{ driving (last)}}{48 \text{ driven (first)}}$$

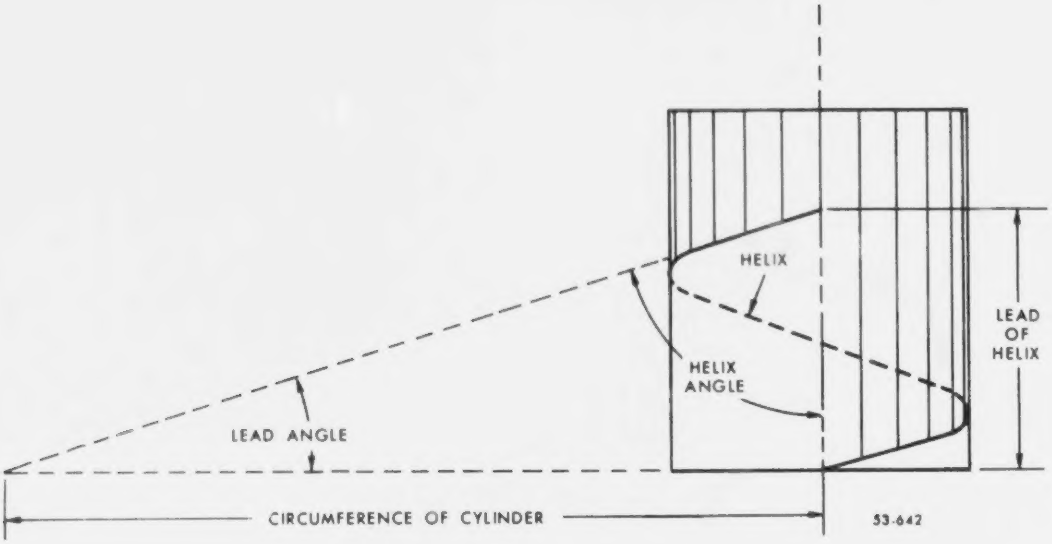

HELIX
LEAD OF HELIX
HELIX ANGLE
LEAD ANGLE
CIRCUMFERENCE OF CYLINDER
53-642

Figure 1-36. Development of a helix.

Thus, the gear with 40 teeth and one of the gears with 32 teeth are driving gears, and the other gear with 32 and the gear with 48 teeth are driven gears. Figure 1-37,A, which shows a typical gearbox, will help you understand where to place the gears. First, place the last driven gear (32) on the splined shaft that rotates the index head worm. Then, in order, place the last driving gear (32) on the stud, the first driven gear (48) on the stud, and the first driving gear (40) on the splined end of the feed screw. Identified by their location, the four gears would be:

Worm gear	32 teeth
First gear on stud	32 teeth
Second gear on stud	48 teeth
Table feed screw gear	40 teeth

If the work does not rotate in the proper direction, you can place an idler gear in the gear train to reverse the direction of rotation, as shown in figure 1-37,B. The calculations to this point are typical for machining most helixes on such things are reamers, drill bits, etc.

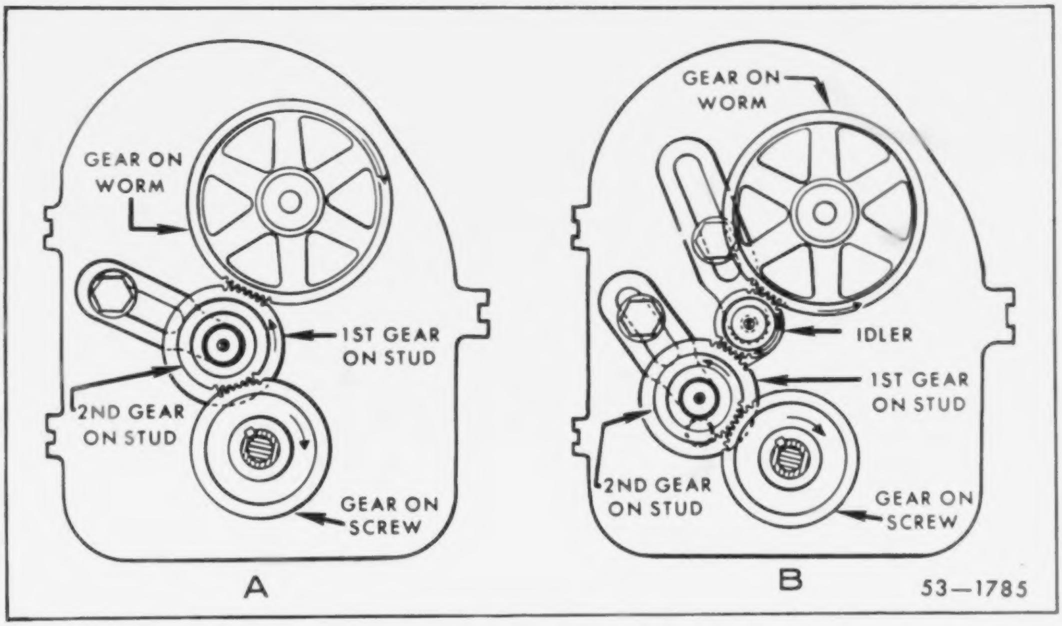

GEAR ON WORM
1ST GEAR ON STUD
2ND GEAR ON STUD
GEAR ON SCREW
A
GEAR ON WORM
IDLER
1ST GEAR ON STUD
2ND GEAR ON STUD
GEAR ON SCREW
B
53—1785

Figure 1-37. Gear train.

Helical gears. You can machine helical gears, figure 1-38, by following the setup procedures just outlined, but instead of using the outside diameter of the gear blank in the formulas, you should use the pitch diameter, as shown in figure 1-39. Consult machinists' publications, such as the *Machinery's Handbook*, to find formulas needed to calculate exact machining dimensions for particular helical gears. Figure 1-40 shows a typical helical gear setup.

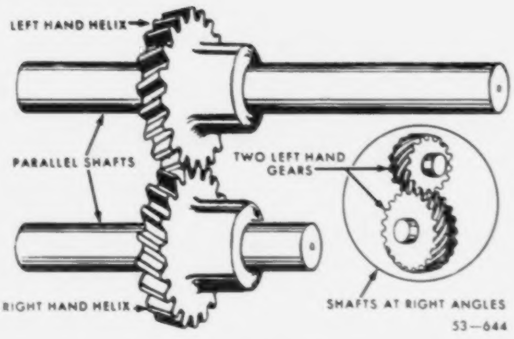


Figure 1-38. Helical gears.

Exercises (412):

1. How is a helix formed on a milling machine?

2. What is the biggest difference between a typical helix and a typical single-threaded screw?

3. What is the lead of a helix if the diameter is 0.500 inch and the tangent of the helix angle is 0.26795?

4. What is the tangent of the angle to which the milling machine table should be swiveled to cut a helix whose diameter is 0.750 inch with a lead of 10 inches?

5. In reference to end gearing for a helical setup, what is compound gearing and why is it used?

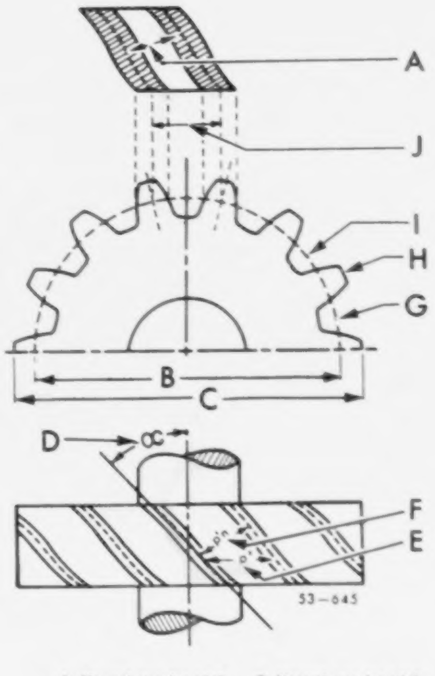
6. If the ratio between the lead of the machine and the lead of the helix does not equal the number of teeth on the available gears, what must you do?

7. How do the calculations for finding the lead of the helix or tangent of the helix angle differ between those for a drill bit and those for a helical gear?

413. Give selected characteristics and calculate specified dimensions of bevel gears.

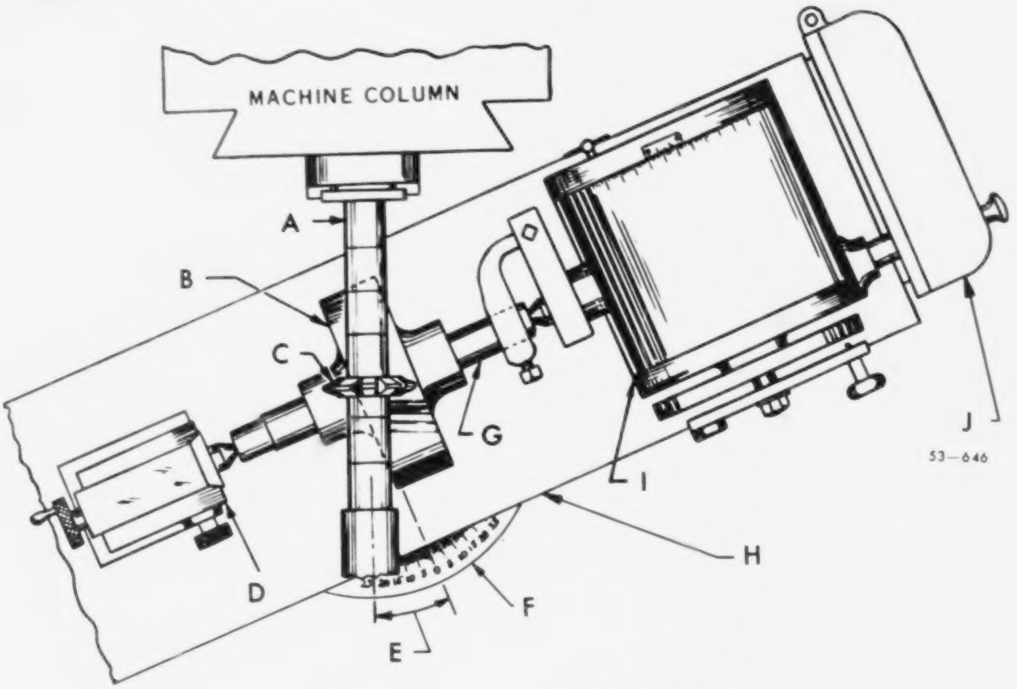
Bevel Gears. Motion can be transmitted between two parallel shafts by the friction between the wheels mounted on the shafts. If teeth of the correct shape are cut on these wheels, a positive uniform motion can be transmitted. These wheels with teeth are called spur gears. Motion can also be transmitted between two shafts that are at an angle to each other by the friction of two rolling cones. If teeth of the correct shape are cut on the faces of the cones, a positive uniform motion can be transmitted. The two cones become a pair of bevel gears. The machining of bevel gears involves problems and terms that are not found in spur gearing. We will discuss these problems and terms and the calculations that are needed in machining bevel gears.

Bevel gears can be mounted on shafts that are at any desired angle, but the most common use of bevel gears is to transmit motion between shafts that are at right angles to each other. If the bevel gears are mounted on two shafts at a right angle to each other and the gears are of the same size, they are called *miter* gears.



A. Normal circular pitch
B. Pitch diameter
C. Outside diameter
D. Helix angle (alpha)
E. Circular pitch
F. Normal circular pitch
G. Pitch circle
H. Addendum
I. Dedendum
J. Circular pitch

Figure 1-39. Helical gear terms.



A Arbor
B Helical gear blank
C Gear cutter
D Foot stock
E Helix angle
F Table graduations
G Mandrel
H Machine table
I Index head
J Gear train box

Figure 1-40. Helical gearing setup.

If one gear is larger than the other, the larger is called the *gear* and the smaller of the two is called the *pinion*. We will use a miter gear mounted on a shaft at a right angle to another shaft as an example for our calculations. For the other angles, nomenclature, and symbols that are used for bevel gears, refer to machinists' publications, such as *Machinery's Handbook*. A knowledge of the nomenclature and symbols, figure 1-41, used for bevel gears will help you understand the calculations.

Assume that you are manufacturing a pair of miter gears with 16 teeth, a 5-diametral pitch, and a pitch cone angle of 45°. The gears are to be mounted on shafts that are 90° to each other. You can calculate for the dimensional values of these gears by using the following formulas. Use these formulas in the order they are given, because the values are progressive from one problem to the next:

Diametral pitch (P) = 5
Number of teeth (N) = 16
Pitch cone angle = 45°

$$\text{Pitch diameter (D)} = \frac{N}{P} = \frac{16}{5} = 3.200 \text{ inches}$$

$$\text{Addendum at large end of tooth (al)} = \frac{1}{P} = \frac{1}{5} = 0.200 \text{ inch}$$

$$\text{Clearance (c)} = \frac{0.157}{P} = \frac{0.157}{5} = 0.0314 \text{ inch}$$

$$\text{The whole depth of tooth (W)} = \frac{2.157}{P} = 0.2314 \text{ inch}$$

$$\text{Dedendum at large end of tooth (dl)} = \text{al} + \text{c or } \frac{1.157}{P} = 0.4314 \text{ inch}$$

$$\text{Thickness of tooth at pitch line (T)} = \frac{1.571}{P} = 0.3142 \text{ inch}$$

$$\text{The pitch cone radius (C)} = \frac{D}{2 \times \sin a} = \frac{3.200}{2 \times \sin 45^\circ} = \frac{3.200}{2 \times 0.707} = 2.263 \text{ inches}$$

Width of face, for gears up to 3 inches pitch diameter (F) =

$$\frac{C}{3} = \frac{2.263}{3} = 0.754 \text{ inch}$$

Width of face, for gears 3 inches to 20 inches in pitch diameter (F) =

$$\frac{C}{4} = \frac{2.263}{4} = 0.5657 \text{ inch}$$

$$\text{Addendum at small end of tooth (as)} = \text{al} \times \frac{C - F}{C} = 0.200 \times \frac{2.263 - 0.5657}{2.263} = 0.150 \text{ inch}$$

$$\text{Thickness of tooth at small end (t)} = T \times \frac{C - F}{C} = 0.314 \times \frac{2.263 - 0.5657}{2.263} = 0.2355 \text{ inch}$$

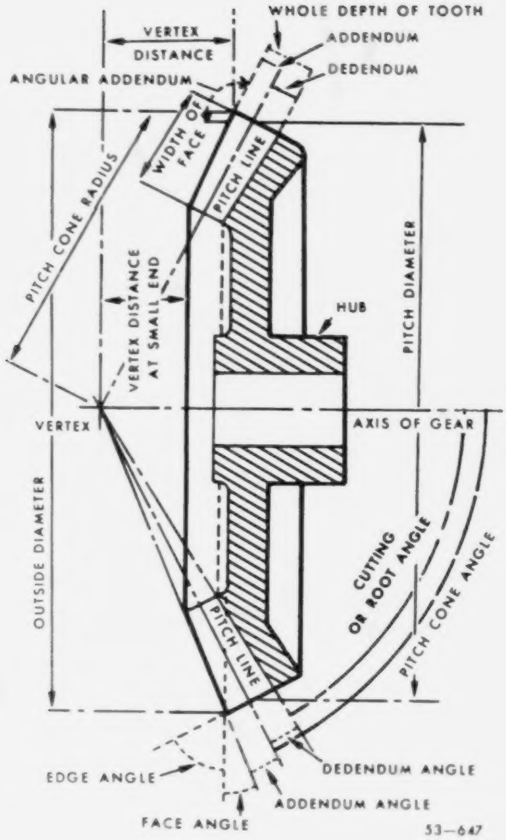


Figure 1-41. Bevel gear nomenclature.

NOTE: You will need a table of trigonometric functions for conversion to degrees.

$$\text{Tangent of the addendum angle} = \frac{\text{al}}{\text{C}} = \frac{0.200}{2.263} = 0.0883 = 5^\circ 3'$$

$$\text{Tangent of the dedendum angle} = \frac{\text{al} + \text{c}}{\text{C}} = \frac{0.2314}{2.263} = 0.10225 = 5^\circ 50'$$

Face angle = pitch cone angle + addendum angle = $45^\circ + 5^\circ 3' = 50^\circ 3'$
Cutting angle = pitch cone angle − dedendum angle = $45^\circ - 5^\circ 50' = 39^\circ 10'$

Angular addendum (K) = al × cos pitch cone angle = $0.200 \times 0.707 = 0.1414$
Outside diameter (OD) = $D + 2K = 3.200 = 0.2828 = 3.482$ inches
Number of teeth used to select cutter (N') =

$$\frac{\text{N}}{\text{cos of pitch cone angle}} = \frac{16}{0.707} = 22.6$$

The cutter selected is for the outer end of the gear teeth, but the curvature at the small end of the gear teeth is too straight. You can compensate for this by filing the teeth at the small end above the pitch line, as shown in figure 1-42. The selected cutter will produce the correct width of tooth space at the small end of the teeth, but will leave the teeth too thick at the large end. Trim the sides of the teeth to correct this error by setting the gear off center and rotating the gear blank until you obtain the desired tooth thickness, as shown in figure 1-43. Using a table of setover factors, which can be found in machinist publications, such as *Machinery's Handbook*, calculate the amount of setover needed. To select the correct factor from the table, you must first determine the ratio of the pitch cone radius to the width of the tooth face. The setover factor listed in the table at the intersection of the column corresponding to the number of the gear cutter you are using and the column nearest the ratio you have calculated is the factor to use. Use the formula:

$$\text{Table setover} = \frac{\text{thickness of cutter}}{2} - \frac{\text{factor}}{\text{diametral pitch}}$$

to determine the amount of setover required. The thickness of the cutter is measured at the pitch line and it must *actually be measured.* Otherwise, identical cutters may have different thicknesses because of sharpening, slightly different clearance angles, etc. The setover for a 5-pitch, 16-tooth gear with a 2.263-inch pitch cone radius and a width of face of 0.5657 inch that is to be cut with a number 5 cutter is calculated in the following manner:

$$\text{Ratio} = \frac{2.263}{0.5657} = \frac{4}{1}$$

The setover factor corresponding to a 4 to 1 ratio and a number 5 cutter is 0.295. The measured thickness of the cutter selected at the pitch line is 0.2317 inch. Using these values, you calculate the setover as follows:

$$\text{Setover} = \frac{0.2317}{2} - \frac{0.295}{5} = 0.116 - 0.059 = 0.057 \text{ inch}$$

Thus, the setover required is 0.057 inch.

The actual setup and machining of the bevel gear is a very simple operation. The cutter is mounted on an arbor and the gear blank is held in the index head by a chuck. The chuck jaws usually grip the gear blank on the gear hub, but in some cases, when the blank has a hole through it, a special arbor is made to hold the gear blank in place. After you bring the center of the cutter and the center of the gear blank into line, tilt the index head to the calculated cutting angle and lock it into position. At this point, pick up the surface of the gear blank with the cutter. Then gash all the teeth to their full depth of tooth. After you have cut the correct number of teeth to their full depth, your next operation is to offset and rotate the gear blank, as shown in figure 1-43. (NOTE: The direction of offset is always opposite the direction of rotation.) After you have completed the offset and rotation, trim the one side of all the gear teeth, then repeat this for the opposite side of the teeth. Your final operation is to hand file all the teeth of the gear above the pitch line, as shown in figure 1-42.

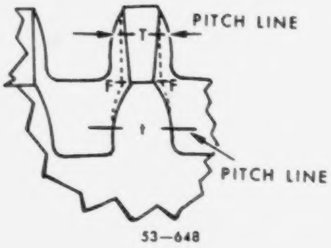


Figure 1-42. Bevel gear tooth.

Exercises (413):

1. In bevel gears, what is the difference between miter gears and a gear and pinion set?

2. Give the nomenclature used for the angle at which you must hold the gear to cut the teeth.

3. You must machine a miter gear having 20 teeth, a diametral pitch of 5, and a pitch cone angle of 45°. Calculate the pitch diameter, the whole depth of the tooth, and the thickness of the tooth at the pitch line.

4. What must you do after you have cut the teeth of a miter gear to their full depth?

1-5. Milling Machine Maintenance

Probably the two most important factors in getting maximum efficiency from the milling machine are proper care and maintenance. Certain periodic adjustments must be made to retain the accuracy permitted by the construction of the machine. The oil in the reservoirs of the column and knee must be changed periodically. Spindle bearings, gibs, clutches, and feed screws must be kept in adjustment if the machine is to function accurately and efficiently.

414. Cite some of the procedures for installing, lubricating, adjusting, and maintaining a milling machine.

Installation and Leveling of the Machine. Occasionally, a milling machine is moved in a shop or a new one is installed. If it is to be placed in an area where there are other machines, a space check should be made before it is permanently placed. Usually a plan dimension drawing is furnished with the machine, which lists the dimensions of the space needed. It is best to allow ample space over and above the exact dimensions of the machine.

The longitudinal table movement is variable on a milling machine and it must have enough space to move without interfering with the machine next to it. Another factor to consider is the floor on which the mill is set. The machine must be level. With a precision level on the machine table, use hardwood wedges, shingles, or shim stock in leveling the machine. The table should be leveled both longitudinally and transversely.

Lubrication. If the machine is run daily, the oil in the column and knee reservoir should be changed about every 4 months. Use a good grade of machine oil SAE 20 to 30. Properly oiling and cleaning a milling

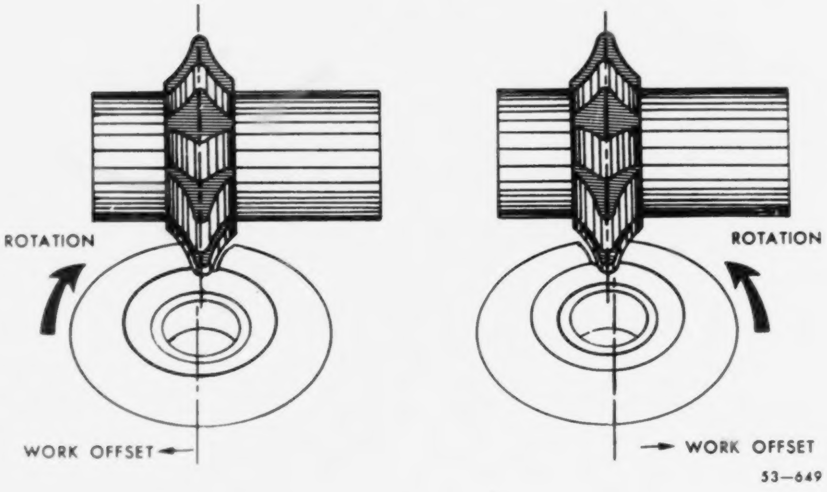


Figure 1-43. Offset and rotation of bevel gear blank.

machine influence its accuracy and efficiency and prolongs its life. Neglect can ruin it.

The working parts that are exposed to dust, dirt, and chips should be frequently cleaned and oiled. Do not let chips collect on the surface of the table until they fall over the sides of the flat bearing surfaces on top of the knee. Be careful to keep chips and dirt from getting between the column and knee, scoring of these flat surfaces and throwing the knee out of alignment. Oil tubes and channels at times become clogged from an accumulation of dirt and oil. You can remove this dirt and oil without damage to the bearing surfaces by flushing the tubes and channels with a flushing oil.

Oil the machine completely before starting it. Many machines of recent design are equipped with automatic lubrication systems that insure a constant supply of lubricant at important points. Check all the oil gages to see that the gages of the column, knee, and saddle reservoirs show oil at a safe level. If the oil in the reservoir is low, the oil pump will not work properly. Too much oil causes leaking and impairs working conditions. Usually there are several points on a milling machine that are hand-oiled. Remember, in applying oil, that an ordinary bearing can hold only a certain amount of oil at a time and applying this amount at regular and frequent intervals is far more beneficial than applying a flood of oil at irregular intervals.

To prevent rust from accumulating on the working and machining surfaces of the milling machine, always keep a light film of oil on these surfaces when the machine is idle.

Adjustments and Maintenance. As we stated previously, there are many parts on the milling machine that you must check and adjust periodically to keep it operating properly. If the adjustments are not made, the quality of your work will drop.

Alignment of table, knee, and column. You can check the alignment and accuracy of the table, knee, and column surfaces by mounting an arbor in the machine spindle and attaching a dial test indicator to the arbor so that the indicator plunger bears on the table. Move the table lengthwise and crosswise and note any variation on the indicator dial. Make these checks with the knee set at various heights. Correct misalignment by adjusting the gibs, rescraping the bearing surfaces of the table, knee, and column or refinilshing the top of the work table.

Gib adjustment. Gibs are usually of the headless taper type and are provided with adjusting screws. To adjust the gibs of the table, saddle, or knee, loosen the screw at the small end of the gib and tighten it by the adjusting screw at the large end. There is another type of tapered gib used on some machines. The only difference between this gib and the one described above is that it has only one adjusting screw on the large end. The set screw moves the gib in or out to tighten or loosen the gib. Its adjustment is correct when the slides move snugly by hand. Proper adjustment is of vital importance. If you adjust the gibs too tight, the slides may be scored. Leave them too loose and they cause chatter, vibration, and undue wear on the machine ways. This condition soon results in an inaccurate machine.

Adjustment of spindle bearings. The spindle bearings on the newer milling machines are the nonfriction or taper roller bearing type. They are properly adjusted at the factory and need not be adjusted for a long time. If you ever need to adjust spindle bearings, place the spindle gearing in the neutral position so that the spindle can be rotated freely by hand. In different makes of machines, the thrust bearing may be located at different places along the spindle. The thrust bearing may be behind the rear bearing or it may be located behind the front bearing. Regardless of its location, its adjustment is the same. First loosen the locking set screw or nut and tighten the thrust nut just enough to remove the slack. With proper adjustment, the spindle can still be turned by hand without too much effort. You can make an accurate check by chucking a rod or bar in the spindle and using it as a lever to move the spindle back and forth along its axis. If you are using a dial test indicator with the plunger of the indicator placed against the nose of the spindle, permit only about .003 inch end play.

Checking the accuracy of the spindle. You can test the spindle by placing a test arbor in it. Set a dial test indicator on the table with the indicator plunger contacting the circumference of the arbor near its outer end. With the spindle rotating, move the table and indicator crosswise and note any variation on the indicator needle. If the spindle is inaccurate, remove it and regrind the tapered hole to restore it to its original accuracy.

Driving clutch adjustment. Several milling machine driving clutches are on the plate disc type. They may be the single plate or multiple plate type, they may be the dry disc type, or they may operate in oil. The drive is similar in operation in that all depend on friction. If the clutch slips under a normal load, adjust it as soon as possible to prevent excessive wear. When the clutch slips, it means that the plates do not come together tightly enough when the clutch is engaged. To adjust the clutch, pull out the plunger lock and turn it in the right direction to tighten it. This direction is usually clockwise, or to the right. It is properly adjusted when you can fully engage the starting lever and when the clutch cone contacts the fingers to compress the driveplates. Your main object is not to set the clutch too tight. A great amount of pressure is engaging the starting lever places a strain on the clutch fingers and may cause them to break.

Adjustment of the table feed screw. The table feed screw is mounted in brackets at each end of the table. The right-hand bracket is provided with two antifriction bearings and an adjusting collar nut for taking up looseness in the bearings. To adjust, remove the cover from the right-hand end of the screw and turn the adjusting collar nut clockwise until one of the ears on the lockwasher of the collar nut slips into place in one of the notches of the adjusting nut.

Adjustment of the crossfeed screw bearings. To adjust the bearing of the crossfeed screw, remove the hand wheel, power feed lever, and graduated dial. A locknut and thrust nut are then exposed. Loosen the locknut and turn the thrust nut to the right. Replace the locknut after you have made the adjustment. On the vertical feed screw, no provision has been made for the adjustment because the weight of the knee prevents "back lash" between the screw and its nut and driving members.

Exercises (414):

1. Before a milling machine is permanently placed in position around other shop machinery, what should be done?

2. How can you prevent rust from accumulating on the machined surfaces of a milling machine?

3. What happens if you adjust the gibs on the milling machines too tightly? Too loosely?

4. At which end of the table is the table feed screw adjusting collar usually located?

5. What must you usually remove to adjust the crossfeed screw bearings to remove excessive looseness?

CHAPTER 2

Shaper Work

ARE ALL MANUFACTURED items cylindrical in shape? Of course not. Many items are rectangular, square, or a combination of several geometric figures. In other words, many objects have flat surfaces that intersect. A machine that is designed primarily to produce flat surfaces is the shaper. In this chapter, we will discuss the various aspects of shaper work, such as the design of shaper cutting tools, work setup devices, simple and special planing operations, and shaper maintenance. We will be referring to various parts of the shaper during our discussion. You can refresh your memory of the location of the parts of the shaper by referring to figure 2-1. It is typical of the shapers commonly used in Air Force shops.

2-1. Shaper Cutting Tools

Like lathe tool bits, shaper cutting tools can be ground into a variety of shapes and sizes to fit a given operation. There are, however, several basic types or styles that you should be familiar with. We will discuss the characteristics of these shaper tools in this section.

415. Describe the characteristics and uses of selected shaper cutting tools.

Shaper Tools. Shaper tools are ground from the same tool steels that are used for lathe tools, but they are usually ground from ⅜-inch by ⅜-inch (or larger) tool blanks. Shaper tools usually have less effective end relief and side relief than lathe tools. You can grind shaper tools as either left- or right-hand tools. We will discuss some of the common types of shaper tools.

Roughing. The roughing tool, also called a bullnose roughing tool, is intended for heavy-duty cutting. It can withstand the pressure of heavy feeds and depths of cut. Figure 2-2 shows the various angles used for a left-hand roughing tool. Left- and right-hand roughing tools can be ground with a smaller nose radius and are used for finishing vertical surfaces.

Steel shear. Steel can be more highly finished with a shear tool than with any other shaper tool. For the best results, use the steel shear tool, shown in figure 2-3, with a depth of cut of less than 0.005 inch and the finest possible feed.

Aluminum shear. Use the aluminum shear tool, shown in figure 2-4, for finishing cuts on aluminum.

Roundnose. The roundnose tool, shown in figure 2-5, has 0° side rake, and cutting edges on both sides. These enable it to cut in both directions. You can use it to rough out metal between two shoulders.

Squaring. The squaring tool, shown in figure 2-6, has sharp corners on the ends of the cutting edge which allow it to produce 90° corners. You use it primarily to finish the bottom and sides of shoulders, keyways, and grooves, as shown in figure 2-7.

Shovelnose. The shovelnose tool is like the squaring tool, except that the ends of the cutting edge are rounded slightly and the back rake angle is reduced. You can use it either as a right-hand or as a left-hand tool to machine vertical surfaces.

Parting. The parting tool is similar to the squaring tool, except that it is much narrower. You use it to part work.

Side finishing. The side-finishing tools, shown in figure 2-8, are ground as right-hand and left-hand tools and are used to finish vertical surfaces. You can also use them for cutting or finishing small horizontal shoulders after you have taken a vertical cut.

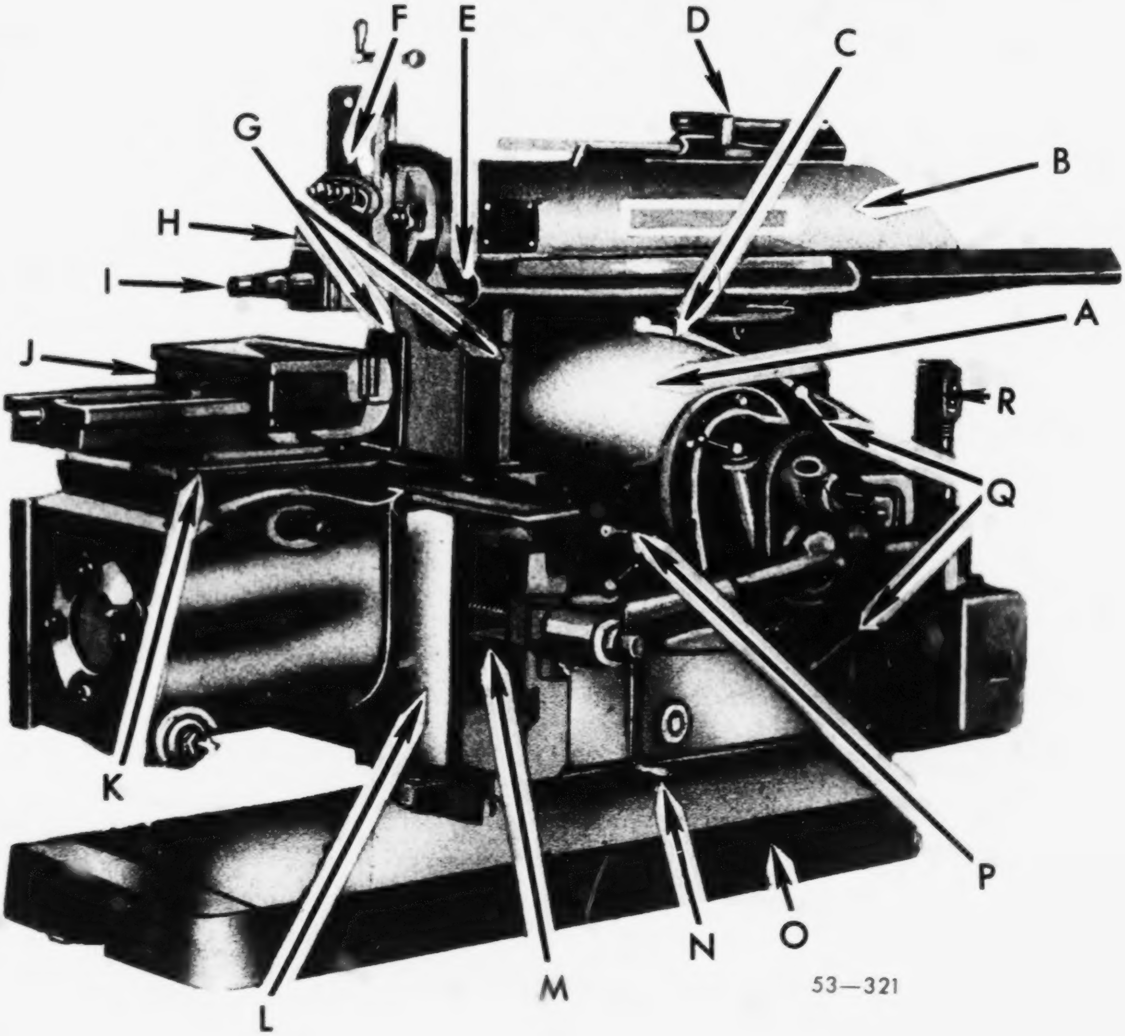
Form. Form tools may be used to cut a specific shape, such as concave or convex radii, V-grooves, etc. They are usually ground with 0° back and side rake. You should rough out the form with a roundnose tool and use the form tool to finish the form.

Exercises (415):

1. Normally, what are shaper cutting tools ground from?

2. What should the end relief angle be on a shaper roughing tool?

3. What depth of cut and feed should be used with a steel shear tool?



53—321

A	Column	J	Vise
B	Ram	K	Tilting surface
C	Clutch lever	L	Trunnion apron
D	Ram positioning shaft	M	Crossrail
E	Dovetail ways	N	Hand traverse crank (crossfeed screw)
F	Tool slide	O	Base
G	Column vertical ways	P	Rapid traverse lever
H	Clapper box	Q	Speed-change levers
I	Tool post	R	Motor switch

Figure 2-1. Universal shaper.

4. What is the primary purpose of the squaring tool?

5. What is the recommended length of the cutting edge on a right-hand side finishing tool?

2-2. Making Work Setups

Now that you know the common types of cutting tools, we will turn to the ways in which they are held in the shaper and how the stock or work is held during the planing operation. We will also discuss the speed and feed requirements for the shaper.

416. Point out the uses of certain tool and work holding devices.

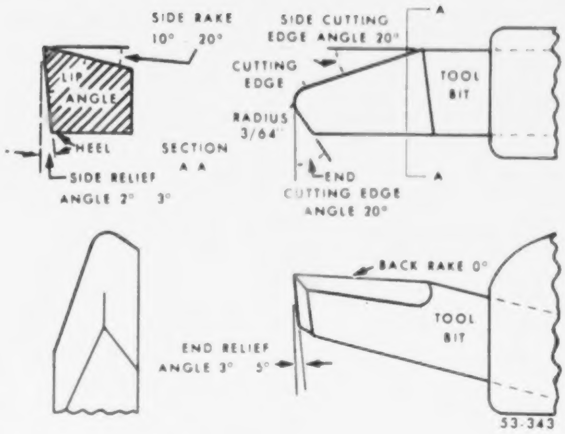

SIDE RAKE
10° 20°
SIDE CUTTING EDGE ANGLE 20°
A
CUTTING EDGE
LIP ANGLE
TOOL BIT
RADIUS 3/64"
HEEL
SECTION A A
SIDE RELIEF ANGLE 2° 3°
END CUTTING EDGE ANGLE 20°
A
BACK RAKE 0°
TOOL BIT
END RELIEF ANGLE 3° 5°
53.343

Figure 2-2. Roughing tool angles.

Toolholders. A variety of toolholders are used for shaper work. The most common toolholders used in shaper work are the straight, the left-hand, and the right-hand toolholders, which are identical to the common lathe toolholders. The straight toolholder is used more frequently in shaper work than in lathe work. The tool is held in the toolholder at an angle of approximately 14°. Do not forget to compensate for this angle when you are grinding the end relief and the back rake angles.

Another type of toolholder is the *swivel head*. It is adjustable and can be used as a straight, right-hand, or left-hand toolholder. Also, it holds the tool straight instead of at a 14° angle as in the more common types of holders. This means that the end relief angles should be less on the tools used in the swivel head type than in the common type.

Still another type of toolholder, the *extension toolholder*, is used when you machine internal splines, keyways, etc. They are similar in construction and use to the boring bars used in lathe work.

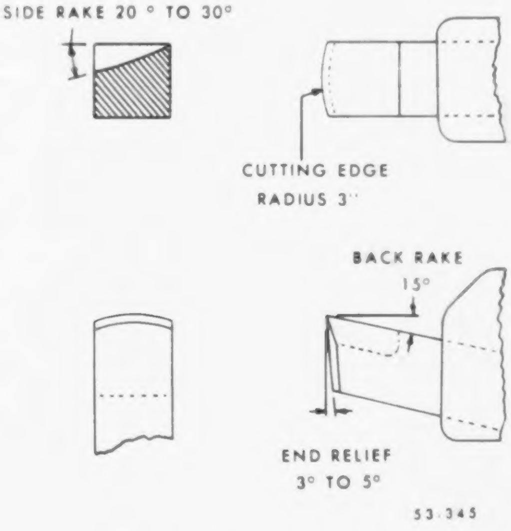

SIDE RAKE 20 ° TO 30°
CUTTING EDGE RADIUS 3"
BACK RAKE 15°
END RELIEF 3° TO 5°
53.345

Figure 2-3. Shear tool for steel.

Work Holding Devices. The shaper is used to machine work that varies greatly in size, shape, and machining requirements. A knowledge of some of the workholding devices can help you select the correct work setups to use. Work being machined in a shaper may be held or clamped by different methods. It may be held in a vise or between shaper index centers. It may be clamped to an adjustable or nonadjustable angle plate or fastened directly to the shaper table with one of several clamping devices. It can also be held in special fixtures.

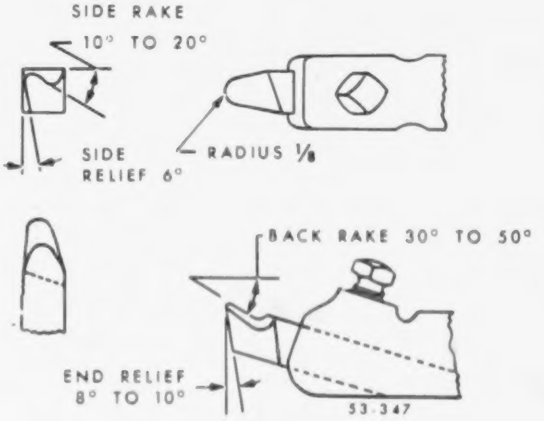

SIDE RAKE
10° TO 20°
SIDE RELIEF 6°
RADIUS ⅛
BACK RAKE 30° TO 50°
END RELIEF 8° TO 10°
53.347

Figure 2-4. Aluminum shear tool.

Vises. There are common types of shaper vises: the double-screw and the single-screw, shown in figure 2-9. The double-screw vise is stronger and has greater holding power than the single-screw vise. You can hold slightly tapered workpieces in the double-screw vise without using extra jaws or shims. The single-screw vise has a faster clamping action. Most shaper vises are swiveled or rotated in a horizontal plane, making it possible for you to position the jaws either parallel or perpendicular to the stroke of the ram, or to any desired angle in between. The base of the vise is graduated in degrees, indicating the angle to which the vise is swiveled. You can swivel the vise without removing it from the machine.

Clamps. You may use a variety of clamps to fasten work to the table of a shaper. The type of clamp that you use depends upon the shape and size of the work to be clamped. Use enough clamps to insure that the work will not move during the machining operation. Figure 2-10 illustrates good and bad clamping practices.

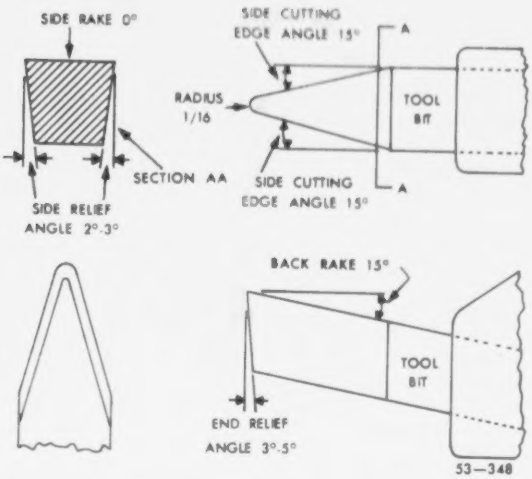

SIDE RAKE 0°
SIDE CUTTING EDGE ANGLE 15°
A
RADIUS 1/16
TOOL BIT
SECTION AA
SIDE CUTTING EDGE ANGLE 15°
A
SIDE RELIEF ANGLE 2°-3°
BACK RAKE 15°
TOOL BIT
END RELIEF ANGLE 3°-5°
53—348

Figure 2-5. Roundnose tool angles.

Parallels. Parallels, as you may recall, are bars of hardened tool steel whose opposite surfaces are parallel to each other. You use them to support the work at a convenient height while you keep the bottom of the work and the shaper table or vise parallel.

Angle plates. Angle plates are fastened to the table of the shaper, and the work is fastened to the angle plate. The two outer surfaces of the standard angle plate, as you may remember from Volume 1 of this course, are perpendicular to each other, which permits you to mount work at any angle of 90° to the shaper table. You can use an adjustable angle plate to support work at various angles between the vertical and horizontal positions, but use it only for light machining operations.

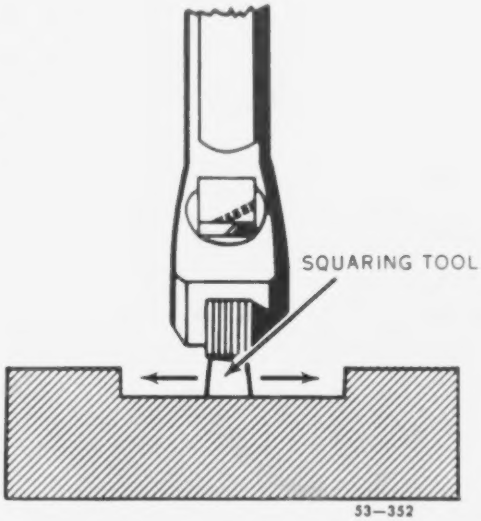

SQUARING TOOL
53—352

Figure 2-6. Squaring tool.

Holddown straps. You use holddown straps to hold thin objects flat against the table or parallel, as shown in figure 2-11. You generally use them when you want to remove a small amount of material from the surface of the work and other clamping methods would be impractical. The contacting edges of the holddown straps are machined at a slight angle, which causes them to force the work down tightly against the table surface or the parallels, as shown in figure 2-11.

Bunters and toe dogs. You use bunters, shown in figure 2-12, to prevent work from shifting sideways during machining. Insert the hooked portion of the bunter in the T-slot of the table and use the threaded screw to lock the work and bunter in position. You can use toe dogs, shown in figure 2-13, with bunters to hold thin work on the table. Figure 2-14 shows correct and incorrect ways to use toe dogs.

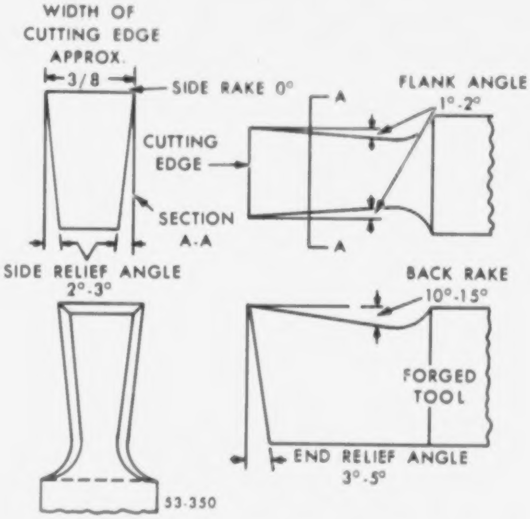

WIDTH OF CUTTING EDGE APPROX.
3/8
SIDE RAKE 0°
A
FLANK ANGLE 1°-2°
CUTTING EDGE
SECTION A-A
A
SIDE RELIEF ANGLE 2°-3°
BACK RAKE 10°-15°
FORGED TOOL
END RELIEF ANGLE 3°-5°
53-350

Figure 2-7. Squaring tool angles.

Exercises (416):

1. If you switched to a swivel toolholder after using a common lathe-type toolholder, what change would you need to make on the tool bit?

2. Explain the difference between the two most common types of shaper vises.

3. What important thing should you remember when you use an adjustable angle plate to support work for a shaper operation?

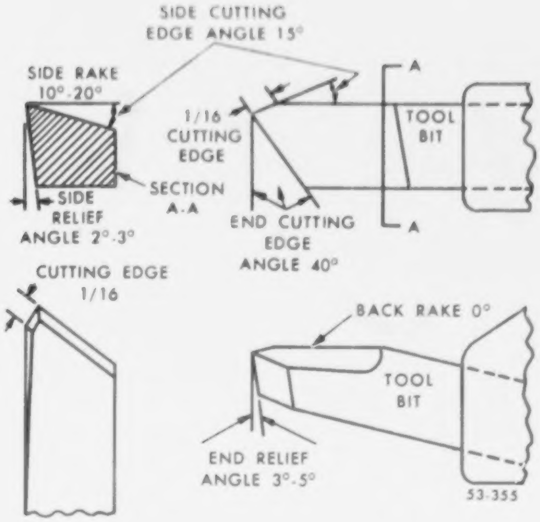


Figure 2-8. Side finishing tool angles.

4. What is the purpose of a bunter when it is used without a toe dog?

417. Explain the ram driving mechanism and the length of stroke setup, analyze the speed and feed requirements, and calculate shaper speed.

Length of Stroke. As you may recall from your 3-skill-level studies, you change the length of stroke on a shaper by turning the stroke adjusting shaft with a handcrank. A dial indicates the length of stroke. Figure 2-15 shows the internal mechanism that drives the ram and provides for varying the length of stroke and the position of the ram.

The driving mechanism consists mainly of a large gear or bull wheel, a rocker arm, and a connecting link. The bull wheel is driven by a pinion. Anchored to the center of the bull wheel is a radial slide which carries one part of a sliding block into which the crankpin fits. The position of this pin and the block is controlled by a small lead screw connected to the operator's side of the machine by bevel gears and a square-ended shaft. The location of the sliding block and pin with respect to the center of the bull wheel governs the length of the stroke.

As the bull wheel and crankpin turn, the other part of the sliding block (which also swivels on the crankpin) moves up and down in a slide in the rocker arm, causing the rocker arm to move back and forth. The top end of the rocker arm is connected to the ram by a link, and the movement of the rocker arm imparted through this link gives the ram a reciprocating motion. The number of strokes that the ram travels per minute is governed by the change gearbox on the operator's side of the machine and is the same as the rpm of the bull wheel.

Normally set the length of stroke at 1 inch longer than the length of the work. The excess length of stroke is known as overstroke and is necessary to provide clearance for the tool bit at the beginning and end of the cut. The cutting tool should extend approximately ⅛ inch beyond the end of the work to permit the chip to break off. The remainder (the greater part at the rear of the work) of the overstroke permits the clapper box to seat properly before each cutting stroke. Since the ram must be positioned with the motor *on*, make sure that the tool clears the dovetail ways before you engage the ram activating clutch.

Speed. The speed of a shaper is expressed in strokes per minute. The number of strokes per minute depends upon the cutting foot speed recommended for the metal and the length of the stroke. Use the following formula to convert the recommended cutting foot speed for shapers, shown in figure 2-16, to strokes per minute:

$$\frac{\text{CFS} \times 7}{\text{L}}$$

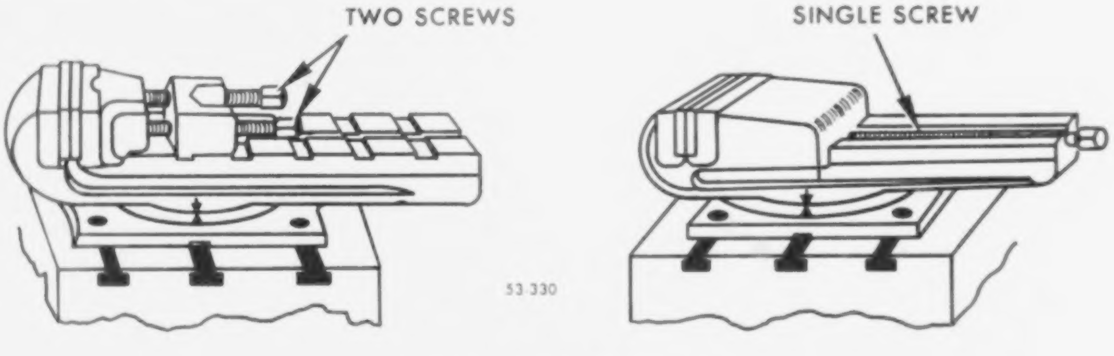
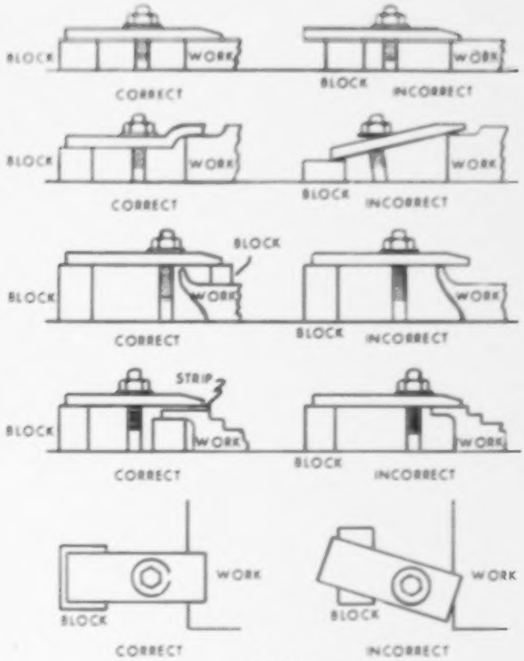


Figure 2-9. Double and single screw vises.


BLOCK
WORK
CORRECT
BLOCK
WORK
INCORRECT
BLOCK
WORK
CORRECT
BLOCK
WORK
INCORRECT
BLOCK
BLOCK
WORK
CORRECT
BLOCK
WORK
INCORRECT
STRIP
BLOCK
WORK
CORRECT
BLOCK
WORK
INCORRECT
WORK
BLOCK
CORRECT
WORK
BLOCK
INCORRECT

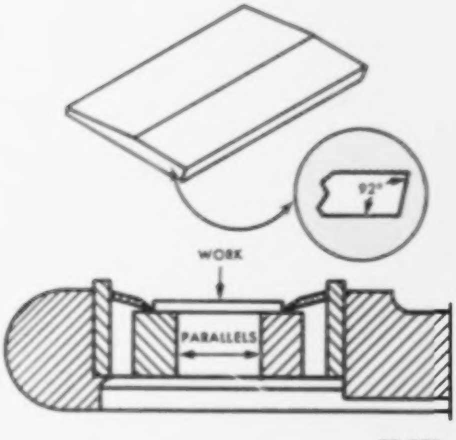
53.332

Figure 2-10. Clamping work.

when:

N = Number of strokes per minute
CFS = Cutting foot speed
L = Length of stroke in inches (including the 1-inch overtravel)

Example: Assume that you are to rough machine a piece of tool steel 11 inches long, using high-speed tools. At what speed should you operate the shaper?


92°
WORK
PARALLELS

53-338

Figure 2-11. Holddown straps.

By consulting a machinist's handbook, you will find that the recommended CFS is 40. Then:

$$N = \frac{40 \times 7}{12} \quad \text{(the length of the work plus the 1-inch overtravel)}$$

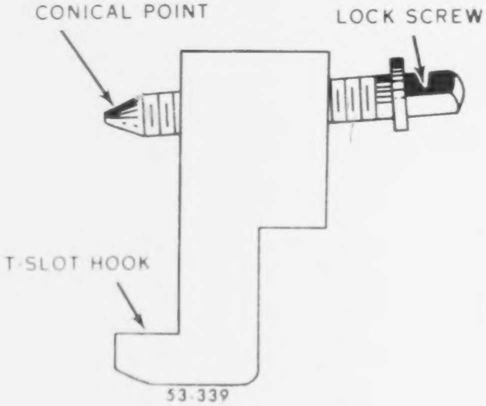
$$N = \frac{280}{12}$$

$$N = 23\,^{1}/_{3}$$

You must set the speed-change levers to the nearest available speed as indicated on the plate showing the lever positions for various strokes per minute. NOTE: To prevent damage to the shaper, you must stop the ram (on most shapers) before you move the speed-change levers.

Take the following factors into consideration when you determine shaper speed:

a. The hardness of the material. Usually, you machine hard material at slower speeds than soft or ductile material.


CONICAL POINT
LOCK SCREW
T-SLOT HOOK

53-339

Figure 2-12. Bunter.

b. Tool shape. Use low speeds for form tools because of the increased area of contact.

c. Tool material. Use lower speeds for carbon tools than for high-speed steel tools.

d. Power, design, and condition of the machine. Use higher speeds on heavy, rigidly constructed machines and on machines that are in good condition than on machines that are intended for light-duty applications. CAUTION: NEVER OPERATE THE SHAPER AT ITS HIGHEST SPEED AND LONGEST LENGTH OF STROKE AT THE SAME TIME. DOING SO MAY DAMAGE THE SHAPER OR MOVE IT OUT OF ALIGNMENT.

Feed. You feed the tool into the work by means of the toolslide in the same way that you use the lathe

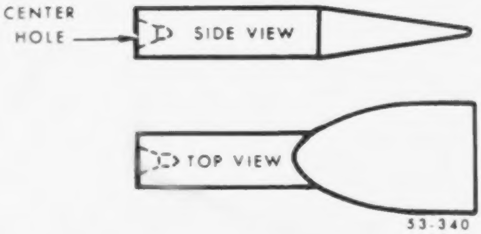


Figure 2-13. Toe dogs.

compound rest to machine a short taper. However, in shaper work, feed is normally understood to mean the rate of crossfeed travel. This is the distance the table moves the work toward the tool just before each cutting stroke. Select the desired rate of feed by positioning the feed selection lever as shown on a graduated plate. The available feeds on a shaper are much coarser than those on a lathe. They range from 0.010 inch on most shapers to approximately 0.170 inch. The right feed to select depends upon the finish you desire and on the depth of cut. The lower feeds generally provide the best finishes while the coarse feeds are used for roughing operations.

Exercises (417):

1. Name the three main parts in the shaper driving mechanism.

2. What action takes place in the shaper mechanism to bring about a change in the length of stroke?

3. Explain how much overstroke should be included in the length of stroke and why it is required.

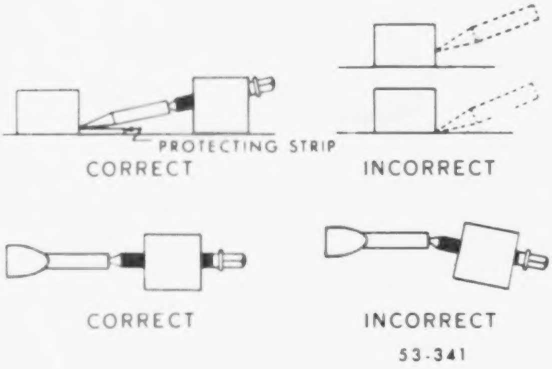


Figure 2-14. Use of toe dogs.

4. How is the speed of the shaper expressed?

5. You must machine a piece of mild steel that is 9 inches long and you want to obtain a CFS of 60. What should the shaper speed be?

6. What speed and length of stroke combination can cause severe damage to the shaper?

7. When does the table feed take place if the power feed is in operation?

2-3. Simple Planing Operations

In this section, we will briefly examine the procedures for squaring a block of metal in a shaper. We will also discuss the procedures for planing vertical surfaces as well as shoulders and corners.

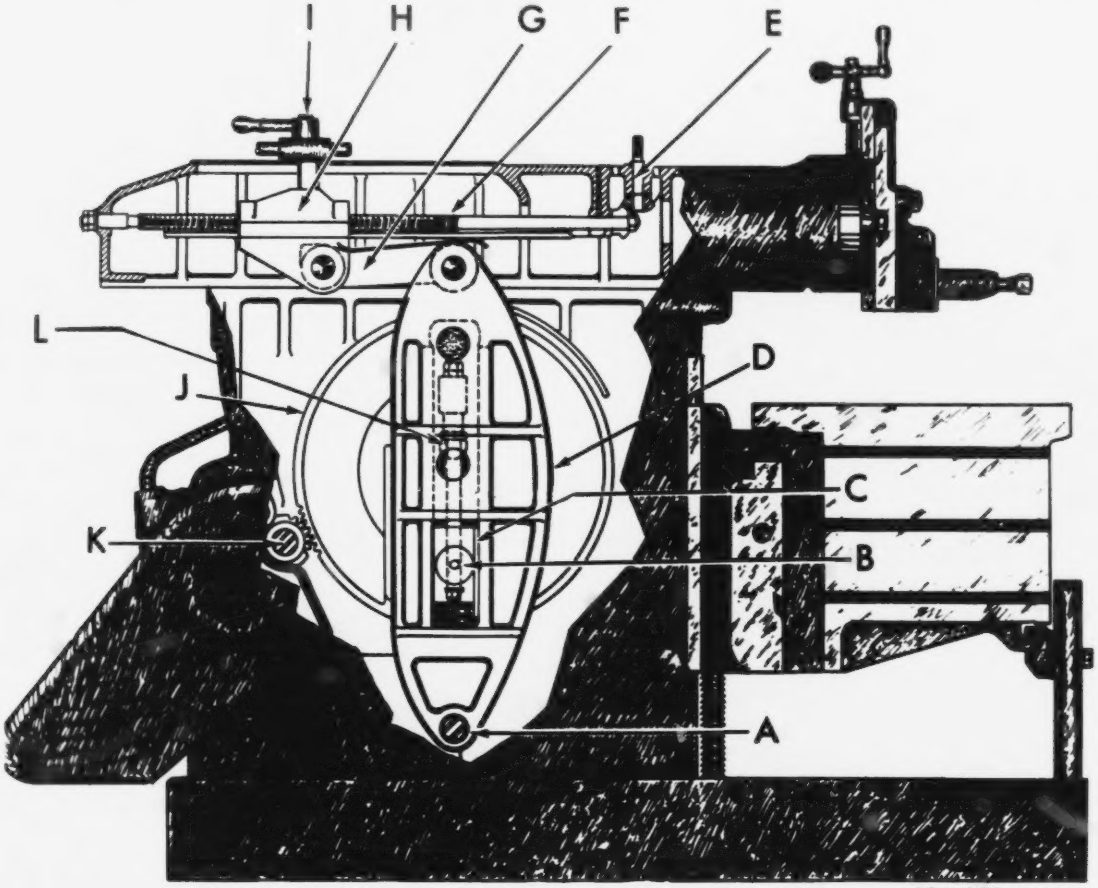
418. Explain key steps in the flat planing technique for squaring a block of metal with a shaper.

Flat Planing. You machine flat surfaces on a shaper by feeding the work below the ram or by feeding the tool past the work with the toolslide. The direction of the feed is usually from left to right in machining horizontal surfaces and from top to bottom in machining vertical surfaces. Using these directions of feed, you have an unobstructed view of the work surface and the cutting action of the tool.

Use a roughing tool and roughing feed to remove excess stock. Take a finish cut with the roughing tool, using a finish feed. This should help remove the taper or spring caused by the heavy cut. NOTE: Use the cutting lubricant that is recommended for the metal you are machining during all cutting operations. Apply the lubricant to the surface with a brush or an oil can. Do not let the brush or the oil can spout get caught between the cutting tool and the work.

You can machine surfaces that are perpendicular to each other by machining them horizontally in the proper sequence. The following information will help you understand how to machine a parallel so that the opposite surfaces are parallel and the adjacent surfaces are perpendicular. Figure 2-17 shows the position of the work as each side is machined.

Obtain the proper size and type of material for the job. Prepare the machine by oiling the necessary points. Then align the stationary jaw and the bottom



53—322

A. Rocker arm shaft
B. Crank pin
C. Sliding block
D. Rocker arm
E. Ram positioning shaft
F. Ram adjustment screw
G. Link
H. Ram adjustment nut
I. Ram clamp handle
J. Crank gear
K. Crank gear pinion
L. Bevel gears

Figure 2-15. Shaper drive mechanism.

of the vise so that they are parallel to the travel of the ram. Mount the work in the vise on parallels of the correct size. The work must extend above the jaws far enough to permit the removal of the necessary material. If the work has a rough surface, use shim stock between the work and both vise jaws and between the work and the parallels. This protects the vise jaws and the parallels from the rough material and gives the vise greater holding power. Smooth or machined surfaces require shim stock only against the movable vise jaw to permit the work to seat on the parallels and also to prevent damage to the finished surface.

To seat work on the parallels properly, tap it lightly with a soft hammer after you have tightened the vise jaws. If you tighten the vise jaws after you have seated the work on the parallels, you may unseat the work.

Tilt the top of the clapper box in the direction opposite to that in which the tool is to cut, except when you use a roundnose tool. With that tool, the clapper box should be perpendicular to the work surface. Mount the toolholder and tool. Calculate and set the proper length of stroke and position the ram properly in relation to the work. Then calculate the amount of material to remove from one side. Be sure to leave enough material for a finishing cut. Set the shaper for the proper speed for the material you are machining. Set the feed for the roughing cut, and rough machine the first side of the work. After roughing the first side, replace the roughing tool with a shear tool for finishing. You can use the roughing tool for finishing if an exceptionally good finish is not required. Set the shaper for the finishing speed, and feed and finish machine the first side.

Materials To Be Machined	Carbon Steel Tools		High Speed Steel Tools	
	Cutting Speed (feet per minute)			
	Roughing	Finishing	Roughing	Finishing
Cast Iron	30	20	60	40
Mild Steel	25	40	50	80
Tool Steel	20	30	40	60
Brass and Bronze	75	100	150	200
Aluminum	75	100	150	200

53-416

Figure 2-16. Recommended shaper cutting speeds.

The second side is machined much the same as the first. Place the work in the vise so that side one contacts the solid jaw of the vise. This position side two in an upright position for machining. Calculate the amount of material to remove and repeat the roughing and finishing operations the same as for side one.

The workpiece now has two sides that are square or perpendicular to each other. To machine side three parallel with side two and perpendicular to side one, place the work in the vise so that side one contacts the solid jaw of the vise and side two rests on parallels. Use paper shims to insure that the work seats properly. Rough and finish machine side three so that the distance between side two and side three is correct. For side four, place the work in the vise with side one resting on the parallels and side two contacting the stationary jaw of the vise. Rough and finish machine side four so that the distance between side one and four is correct.

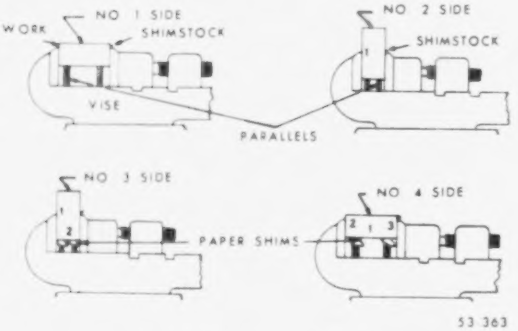


Figure 2-17. Squaring a block.

Exercises (418):

1. What are the best directions for feeding the work or the toolslide during a flat planing operation? Why?

2. How should the vise be aligned for squaring a block of metal?

3. Why should shim stock be used between the work and the movable vise jaw even though the work has smooth surfaces?

4. When you are squaring a block on the shaper, what should be the position of side one (the first side machined) while side three (the third side machined) is being machined?

419. Give the best tool, position, and setup for specific conditions in vertical surface planing.

Vertical Surfaces. When you machine vertical surfaces, such as the vertical surfaces of shoulders or the ends of work, position the toolhead square with the table or vise. Position the vise jaws square or parallel to the travel of the ram, depending upon the location of the surface that you are machining. When great accuracy is not required, you can align the toolhead and the vise by means of their graduations. When

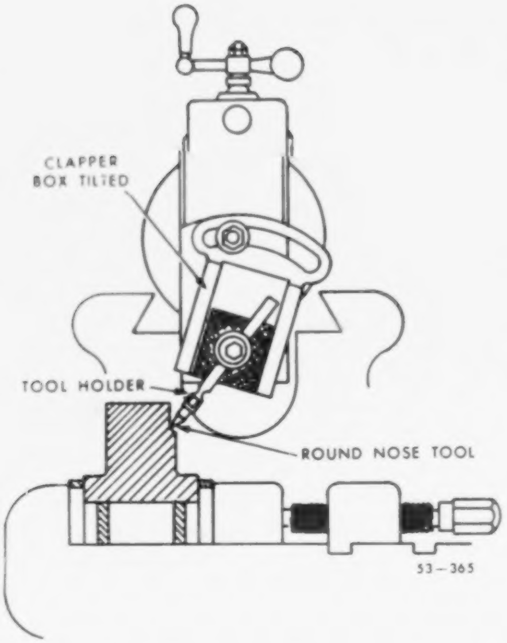


Figure 2-18. Tilting clapper box for down cutting.

greater accuracy is required, use the dial indicator. Hand feed the tool with the toolslide crank and make the depth of cut by moving the work toward the cutting tool. You can use the crossfeed dial graduations to determine the exact depth of cut. Tilt the top of the clapper box away from the surface being machined, as shown in figure 2-18. You can use a roundnose tool for both the roughing and the finishing cuts when average finishes are permitted. Use side-finishing tools when finer finishes are needed and when you are facing deep vertical surfaces on shoulders and corners. Use squaring tools to finish the vertical surfaces on shallow shoulders and corners and to finish the sides of deep slots or grooves.

If a fine finish is required, first rough the surface with a roundnose tool and leave no more than 1/64-inch for finishing. Then install a side finishing tool and proceed in the following manner. Mount a side finishing tool in a straight toolholder. The toolholder should be positioned in the toolpost so that the 1/16 inch position of the tool's cutting edge (refer to fig. 2-8) is parallel to the surface to be finished. The best way to position the cutting edge is with a machinist's square, as shown in figure 2-19. Set the machine to the proper length of stroke. Reduce the CFS to about 30 feet per minute to protect the small cutting edge. With the tip of the tool touching the bottom surface of the corner or shoulder, set the vertical feed dial at zero. NOTE: Omit this step when you use the side-finishing tool to finish the ends of the work. To plane wide, deep grooves, leave 0.005 inch on the bottom surface for finishing with a squaring tool. Pick up the vertical surface of the work, using a strip of paper. Use vertical cuts to finish the shoulder or end of work to the correct size. Do not exceed a depth of cut of .004 and a feed of .002.

Exercises (419):

1. How should the toolhead and the clapper box be positioned for vertical planing?

2. What shaper cutting tool is best for finish planing the vertical surfaces of a square groove ½ inch deep and 1 inch wide when an extremely high finish is not required?

3. If a fine finish is needed on a vertical surface, what tool should you use and how should it be set up?

4. When you are planing a very accurate finish on the past part of a vertical next to the bottom of a shoulder, for what rate of feed should you set the power feed?

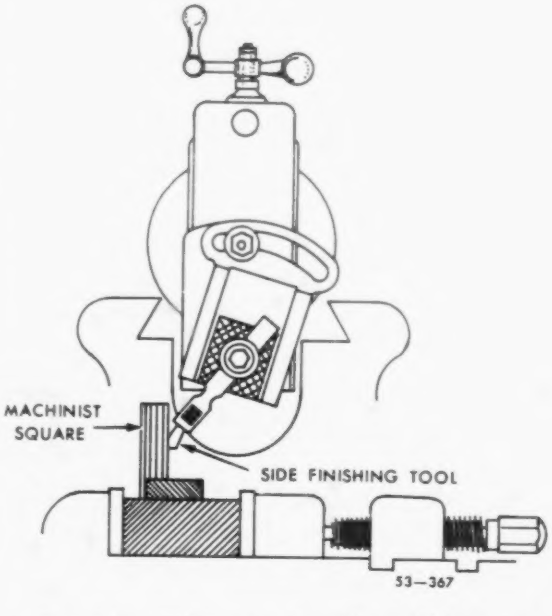


Figure 2-19. Aligning cutting edge with a machinist square.

420. Describe key procedures in machining shoulders and corners.

Shoulders and Corners. Shoulders and corners are machined by removing excess material with a roundnose tool and then finishing with a side-finishing tool or a squaring tool.

You can remove excess material by making a series of horizontal cuts toward the layout line or shoulder. When you are roughing out material between two shoulders, feed the work in both directions. This saves time because you do not have to return the work to a starting point for each cut. When you are roughing between shoulders, the clapper box should be positioned centrally and the toolholder set vertically. Set up the tool as shown in figure 2-20 when you are machining one shoulder. Make each succeeding cut slightly shorter than the preceding cut, leaving a stepped fillet in the corner. Tilt the toolholder to machine closer to the shoulder and to keep the toolholder from interfering with the cut.

The following information will help you understand how a square shoulder, such as the one on the forming die, shown in figure 2-20, is roughed out. Mount a roundnose tool in a straight toolholder. Set the machine for the length and position of stroke and the correct speed. Make sure that the ram and toolslide will clear the work and vise. Pick up the cut with a piece of paper and set the toolslide dial to zero. Make the necessary calculations to determine the depth hfrom the top of the work to the bottom layout line. Begin the cut approximately 1/32 inch from the vertical layout line. Use a roughing feed. You can use the power feed to machine within ⅛ inch of the layout line and then feed by hand to within 1/32 inch of the line. Move the work back to the starting point of the cut and set the toolslide for an additional depth of cut. Engage the power feed and allow the table to feed until the tool is within ⅛ inch of the shoulder. Feed the work by hand until the tool is within 1/64 inch of the point where the preceding cut stopped. (CAUTION: Be sure that the toolholder clears the work as the depth of the shoulder increases.) Repeat the operations until you obtain the depth you want. NOTE: You can measure the height of the shoulder with a depth micrometer but be sure that you remove all burrs from the shoulder before you make the measurement. Leave approximately 0.015 inch for additional cuts on the horizontal surface.

Swing the clapper box away from the shoulder and position the tool at a 30° to 40° angle with the shoulder. Pick up the vertical surface of the shoulder and set the crossfed graduated collar at zero. Position the work and the tool bit with the crossfeed and toolslide so that the tool bit contacts the horizontal surface of the work. Then set the toolslide graduated collar at zero. Rough out the stepped material adjacent to the shoulder to within 0.005 inch of the vertical layout line. (NOTE: You do this by making a series of vertical cuts. Use the zero setting of the toolslide and the crossfeed graduated collars as reference points for each cut. Move the work for the depth of cut with the crossfeed, and move the tool bit downward with the toolslide for the feed.) Feed the tool downward to within 0.005 inch of the horizontal line. Feed the work away from the tool bit by engaging the power feed.

You have now machined both the vertical and horizontal surfaces to within 0.005 inch of the layout line. If the fillet, or corner, formed by the nose radius on the tool bit is not objectionable and the finish produced by the roundnose tool is acceptable, you can machine the shoulder to the finished dimensions. If you need a better finish and a square corner, you can machine the vertical surface with a squaring tool or both the vertical and horizontal surfaces with a squaring tool. You obtain the best finish when you use both the side-finishing tool and the squaring tool.

Exercises (420):

1. When you rough machine material between two shoulders with a roundnose tool, how should the clapper box and toolholder be positioned?

2. You are rough machining material to a shoulder with a roundnose tool. At what distance should you stop the power feed and begin hand feeding toward the shoulder layout line?

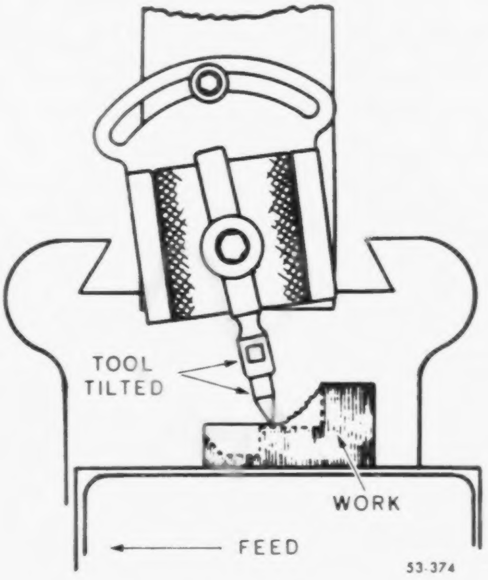


Figure 2-20. Roughing excess to one shoulder.

3. As you near the full depth of a shoulder during a roughing operation, you can check the depth with a depth micrometer, but what must you be sure to do first?

4. After you have machined both the horizontal and vertical surfaces of a shoulder to within 0.005 of an inch and you need a very fine finish and a square corner, what tooling should you use for each operation?

2-4. Special Planing Operations

In this section, we will examine some of the more complicated and special operations that can be performed on the shaper. Cutting grooves, including keyseats and parting, is an operation we will discuss in this section, as well as angular planing and planing irregular shapes.

421. Explain specified points in the techniques of cutting grooves for parting and for internal and external keyseats.

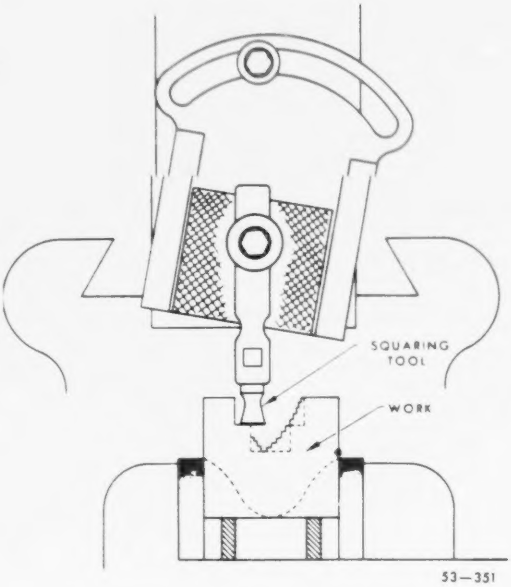


Figure 2-22. Machining a wide groove.

Grooves. You can machine small slots and grooves with form tools, as shown in figure 2-21, or you can rough out large slots and grooves with a roundnose tool and finish machine them with finishing tools, as shown in figure 2-22. Use square-nose tools to finish square and rectangular slots and left- and right-hand side-finishing tools to finish machine V-slots. You can cut off or part work with a shaper by simply machining a narrow slot deep enough to separate the work. Shaper parting tools are identical to the squaring tool except for the width of the cutting edge. Grind the cutting edge on shaper parting tools from 1/8 to 3/16 inch wide. CAUTION: Do not attempt to part work or machine deep grooves parallel with the vise jaws. The pressure of the vise jaws may cause the groove to close slightly and bind on the cutting tool.

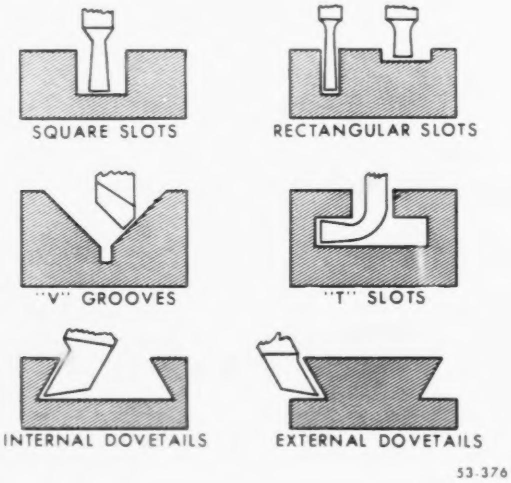


Figure 2-21. Slots and grooves.

A square or rectangular keyseat is in reality nothing more than an external or internal slot or groove that is parallel to the axis of a shaft or hole and fitted with a key. The terms "keyway" and "keyseat" are often used interchangeably. The cutting tool that you use to machine a keyseat is similar to the square-nose tool, except for the width of the cutting edge. The cutting edge should be of the same width as the key that will be used in the keyseat. Before machining a keyseat, lay out its location, width, depth, and centerline accurately. Extend the centerline of the keyseat down the end and through the axis of the work. The extended centerline will help you align the work and cutting tool. A slow operating speed and a depth of cut of less than 0.010 inch will help keep the tool from springing. Both external and internal keyseats can be machined with a shaper. First, we will present the information you need to machine external square keyseats and then the information pertaining to internal square keyseats.

External keyseats. If the keyseat you are to machine does not extend the full length of the shaft, drill a hole at the point where they keyseat will terminate, as shown in figure 2-23,A. The diameter of the drill

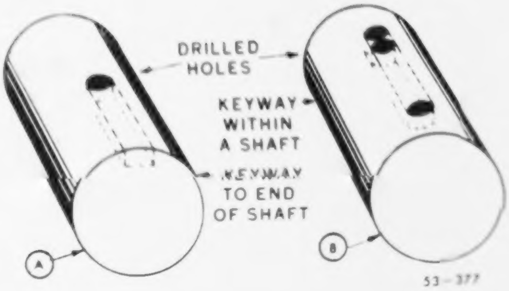


Figure 2-23. Drilled holes for keyseats.

should be equal to the width of the keyseat. The depth of the drilled hole, excluding the conical point of the drill, should be equal to the depth of the keyseat. The hole prevents chips from building up in front of the cutting tool and permits machining the keyseat to its full length. If both ends of the keyseat terminate on the shaft, drill holes at both ends of the keyseat, as shown in figure 2-23,B. Drill another hole adjacent to the hole on the end of the keyseat where the cut will originate, as shown in figure 2-24. Remove the metal between the holes with an end mill or by chiseling and filing. The elongated hole permits the cutting tool to drop into position. Grind away the back portion of the tool bit, as shown in figure 2-24, to provide additional clearance between the tool and the sides of the holes. Position and set the length of the stroke carefully. If the length and location of the stroke are incorrect, the tool or the work could be damaged, or *you* could be injured, *so be careful*! Measure the depth of the keyseat along the side from the bottom to the edge formed by the intersection of the side and the circumference of the shaft. You can find the recommended dimensions of keyseats for shafts of various diameters in machinists' publications, such as *Machinery's Handbook*.

You can machine an external keyseat in the following way: Lay out the keyseat, extending the centerline over the end of the shaft. Drill holes at the ends of the keyseat. Mount the work on the shaper, aligning the centerline with a machinist's square, as shown in figure 2-25. Position the clapper box in the vertical position and mount the cutting tool and toolholder, aligning the cutting edge horizontally. Position the keyseat under the cutting tool. Set the machine for the proper length of stroke and speed. Carefully position the stroke, checking to insure that the tool will not overrun the drilled holes. Pick up the top surface of the shaft. Machine the keyseat to the required depth. NOTE: The total depth of cut can be determined by the following formula:

$$D = \frac{W}{2} + f$$

when

D = depth of cut
W = width of key
f = height of arc

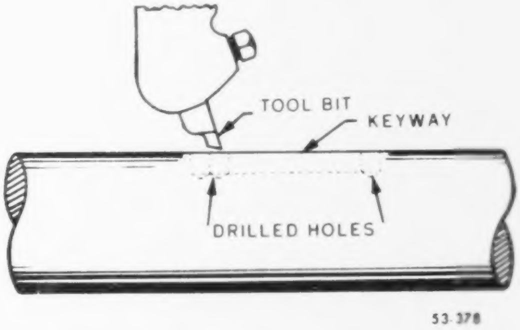


Figure 2-24. Keyseat slotting tool.

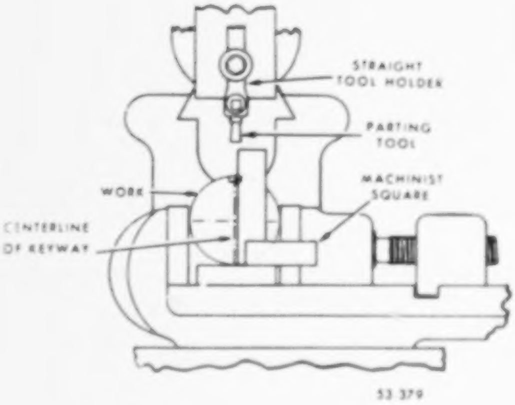


Figure 2-25. Aligning work with a machinist square.

(The height of arc can be found in machinists' publications, such as *Machinery's Handbook;* also refer to keyseat calculations in Chapter 1 of this volume.) Insert a key of the proper size in the keyseat and measure over the key and the diameter of the shaft to insure that the keyseat is the required depth. NOTE: The micrometer reading over the key and the shaft can be determined by the following formula:

$$M = D + \frac{W}{2} - f$$

when

M = micrometer reading
D = diameter of shaft
W = width of key
f = height of arc

Deburr the keyseat and remove the work from the shaper.

Internal keyseats. Internal keyseats are machined with a setup like the one shown in figure 2-26. Note that the clapper box is in the vertical position and locked to keep it from moving, and that the tool is held in an extension toolholder and fed upward for the depth of cut. Internal keyseats are machined in much the same way as external keyseats.

Exercises (421):

1. When you are parting work with the shaper, what important precaution should you keep in mind about holding the work?

2. How wide must the cutting edge of a tool be to cut an external keyseat?

3. How should you prepare the work when you must cut an external keyseat that does not extend off either end of the shaft?

4. How should you check a keyseat to be sure that it is the required depth?

5. Describe the setup for cutting an internal keyseat.

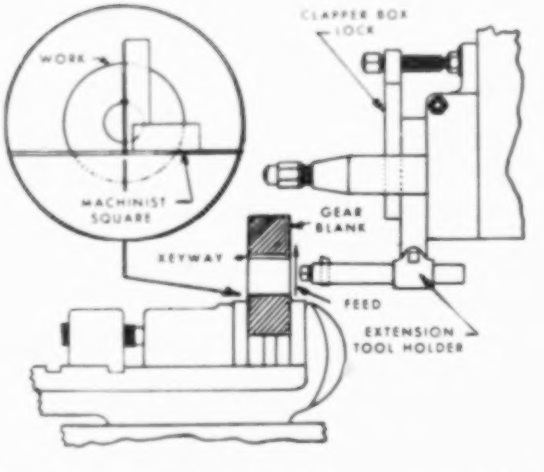


Figure 2-26. Aligning gear and positioning extension toolholder.

422. List the ways to machine angular surfaces and, given specific conditions, select the best way.

Angular Planing. You can machine angular surfaces by: (1) swiveling the vise, (2) swiveling the toolhead, (3) swiveling or tilting the table, and (4) by mounting the work either on an adjustable angle plate or on a fixture.

Swiveling the vise. If the surface to be machined is perpendicular to the surface of the table (or to the bottom of the vise) and at an angle to the stroke of the ram, you can machine it by simply swiveling the vise. Swivel the vise until the angular surface is parallel to the stroke of the ram. Make the depth of cut by moving the table until the work touches the cutting tool. Then feed the tool vertically with the toolslide handcrank. Use the same tooling setup that you use to machine vertical surfaces.

Swiveling the toolhead. The toolhead can be used to machine surfaces that are parallel to the stroke of the ram but at an angle to the vertical centerline of the toolhead. Swivel the toolhead to the required angular setting and feed the tool by hand with the toolhead crank. Use the toolhead graduations for angles requiring average accuracy. Align the toolslide with a dial test indicator and a sine bar, as shown in figure 2-27, when you are machining angles that must be highly accurate.

As you may recall from your study of special tools in Volume 1 of this course, a sine bar is an extremely accurate bar of metal to which to cylindrical reference discs are attached. The centers of the reference discs are either exactly 5 or 10 inches apart. You can position the sine bar at any desired angle by elevating one end of the sine bar and placing the reference disc on a stack of gage blocks of the correct height. Gage blocks are extremely accurate blocks of metal of varying thickness. You can clamp the sine bar to a support bracket at the position you desire so that you can align the toolhead parallel to it with a dial test indicator. You can find the height of the gage blocks needed to obtain a given angle (in minutes of a degree) in machinists' publications, such as *Machinery's Handbook*, or you can calculate it by using the formulas given in Chapter 5 of Volume 1 of this course.

Swiveling the table. You can position the work at the angle you want by swiveling the table on the trunnion or by tilting the tilting tabletop. Use the graduations on the table for average accuracy, or a sine bar, as shown in figure 2-28, for extreme accuracy. Set up the tool and feed the work in the same manner that you use to machine a horizontal surface.

Using an adjustable angle plate. You can mount work on an adjustable angle plate in order to machine it at the angle, or combination of angles, that you desire. They will be the same as those you can machine by swiveling the vise, swiveling the table, or by tilting the tabletop. But you should use the adjustable angle plate for light-duty applications only.

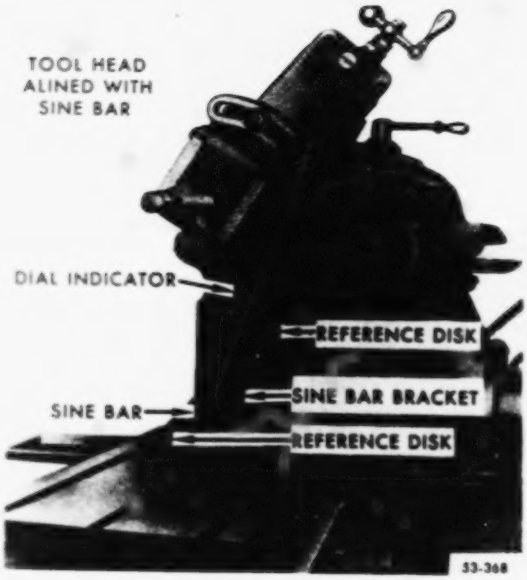


Figure 2-27. Aligning toolhead with a sine bar.

Using a fixture. You can mount work on a fixture, as shown in figure 2-29, to machine an angular surface in the same way that you machine a horizontal surface. You can manufacture fixtures that hold work at any angle you need. However, the time required to manufacture a fixture is not justified unless the work recurs, or you are machining several identical items.

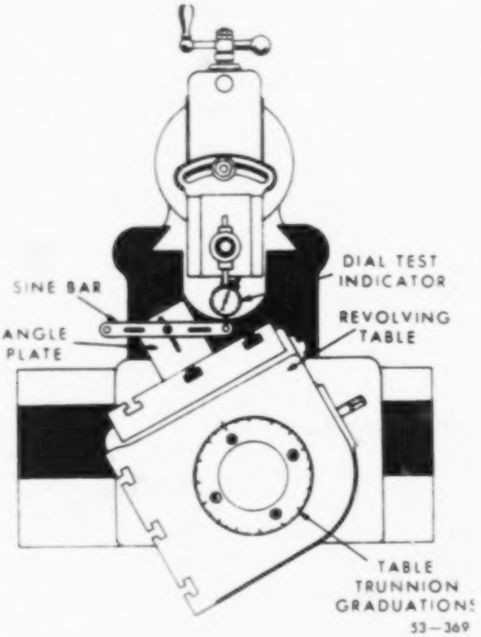


Figure 2-28. Aligning table with a sine bar.

Exercises (422):

1. List the ways that angular planing can be done on the shaper.

2. When you plane an angular surface by tilting the toolhead, how should you set the required angle if only average accuracy is necessary? If great accuracy is necessary?

3. You must machine several angles on a part and you have determined that it must be mounted either on an adjustable angle plate or on a simple fixture that you would have to make. You know that several heavy cuts will be needed if the job is to be done efficiently. Which workholding method should you choose? Why?

423. Explain the techniques for machining irregular shapes.

Irregular Shapes. In addition to straight surfaces, which are machined horizontally, vertically, or at an angle, you can also machine irregular or contoured surfaces with a shaper. While horizontal, vertical, or angular surfaces may connect the curved portions of object, only the curved areas are considered to be contoured. The contour may consist of a single radius, or it may have several curves, such as the contoured surface shown in figure 2-30.

You can machine contour surfaces with a shaper by first laying out the contour on the end of the work blank and then cutting the contour with form tools or by moving the work and tool bit. Normally, you use form tools to machine several identical items. If the contour is too large to be formed by one tool bit, you can grind tool bits to the shape of portions of the contour and then machine the contour by sections. You will obtain the best results by roughing out the contour with a roundnose tool before using the form tools. You can machine contours that are not practical to produce with form tools by moving the work and the tool bit simultaneously so that the tool bit follows the layout line. You can feed both the work and the tool by hand, an operation that requires a great deal of skill and experience, or you can feed the work by power and the tool by hand. You can machine a fairly accurate and uniform contour with this method, since it enables you to concentrate mainly on feeding the tool. Use a roundnose tool to machine the contour. NOTE: Place the clapper box in the vertical position when you machine a contour. If necessary, you can file and

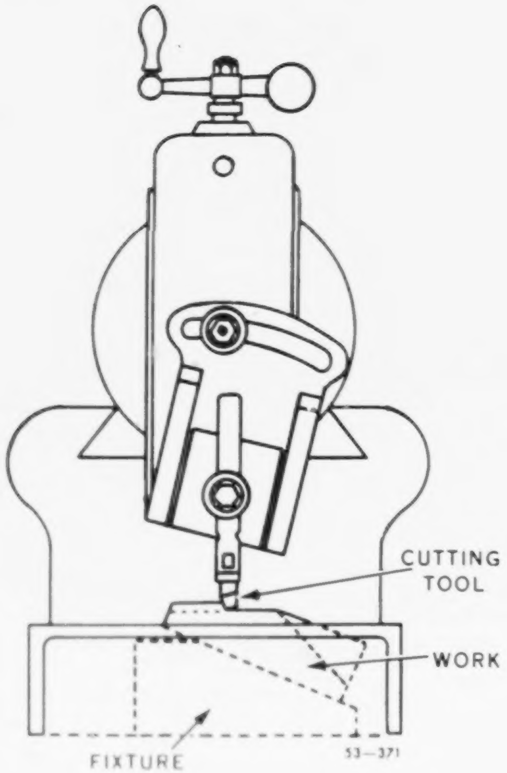


Figure 2-29. Angular planing with a fixture.

polish the contour after machining it to imporve its shape and finish.

Exercises (423):

1. What method should you normally use to machine several small identical curved surfaces?

2. Explain how to machine large contoured surfaces with the shaper.

2-5. Shaper Maintenance

A shaper is usually shipped from the factory in a single crate or box and is almost entirely ready for use as soon as it is placed in position and properly lubricated. Normally, the machine is covered with a preservative, such as a heavy grease, to protect it from corrosion and rust. In this section we will discuss (1) installation, (2) cleaning, (3) adjustments, and (4) lubrication.

424. Give selected procedures for maintaining a shaper.

Installation. A shaper should be installed on a concrete foundation. If this is not available or practical, it can be set on a solid wood floor and held down by heavy lag bolts. When you are installing a shaper, you must pay particular attention to the amount of floorspace needed. Allow ample room for the ram travel, and ample room for an operator to move around the ends and sides of the machine. The manufacturer usually furnishes a dimension plan for reference when you locate the machine in your shop.

Cleaning. Before operating a newly installed shaper, you must clean the preservative from the machine. Many types of preservatives are used, but the most common type is a heavy grease. You can remove the grease and most of the other preservatives with a cleaning solvent. Be very careful with cleaning solvents as most of them are flammable and should be used only in well-ventilated areas.

Adjustments. To keep the shaper in the best operating condition, make periodic inspections and minor adjustments. The periodic inspections should include checking the levelness of the machine, the condition of the clutch and brake assembly, and the adjustment of the gibs, the belts, and the rail clamp.

Leveling. The shaper must be leveled with a precision level. Place the level crosswise on the table and lengthwise on the top of the column. Clamp the crossrail to prevent it from moving. The machine should be level to within 0.001 of an inch per foot. Level the shaper by placing shims under the supporting points of the machine.

Clutch and brake assembly. After a long period of time, the clutch and brake assembly may require adjustment. If this adjustment ever becomes necessary, refer to the applicable technical order or the manufacturer's handbook on the care and maintenance of the specific machine on which you are working. The normal operational test for action is made with the ram stroking and the clutch engaged; a light push on the clutch lever should stop the machine automatically.

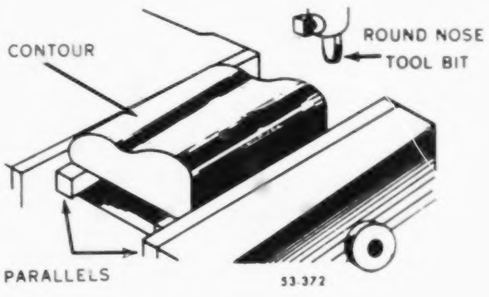


Figure 2-30. Machining a contour.

Gibs. Most shapers are gibbed throughout to maintain proper clearance between working parts. Correct adjustment of gibs is necessary for accurate and smooth operation, and also, for the elimination of excessive chatter during cutting operations. Gibs are usually adjusted with a minimum of clearance. They should be drawn up snugly, and the adjusting screw backed off to provide a clearance of about 0.002 inch between the bearing surfaces.

Belts. The adjustment of the motor drive belts is usually not an involved operation. You can do it on most machines by loosening the nuts holding the motor base and turning an adjusting screw at the bottom of the base. Whether you want to tighten or loosen the belts determines the direction to turn the adjusting screw. The belts should be tight enough so that they do not slip under a normal load but not so tight that they stretch and possibly break.

Rail clamp. To adjust the clamp on the right end of the rail, apply a wrench to the clamp shaft to loosen the mechanism and then traverse the table to the left end of the rail. Turn the adjusting screw tight against the toggle and back it off about one-half turn. Reverse the procedure for the clamp on the left end of the rail. You may have to make additional minor adjustments for the best clamping condition, depending upon the variation of limits and unequal wear on the mechanism.

Lubrication. Oiling the shaper is often neglected during high-production periods. When the machine operates continuously, oil it at least once each day. Proper attention to lubrication will greatly increase the life of the shaper and hold maintenance to a minimum. The oiling should be done progressively. Shapers of recent design are equipped with an automatic lubricating system that insures a constant supply of clean lubricant at important points. Check the oil gages to make sure that the oil is at a safe level. If the oil is low in the reservoir, the oil pump cannot operate properly. There are many points on the shaper that must be hand oiled. A small amount of oil applied at regular intervals is better than a floor of oil at irregular intervals.

Periodic oil checks and changes are necessary in preserving the life of the machine. When you change the oil, which should be done approximately every 12 months of normal operation, consult the applicable technical order or the manufacturer's operator manual for the specific oil and the amount to use.

Exercises (424):

1. What are the two prime factors to consider when you are preparing to install a shaper?

2. What precaution should you observe when cleaning a newly installed shaper with cleaning solvent?

3. When the gibs on the shaper are properly adjusted, how much clearance is there between bearing surfaces?

4. State a good general rule of thumb for lubricating a shaper.

CHAPTER 3

Grinding Machine Work

GRINDING MACHINES use a rotating abrasive wheel to dress, shape, or finish work surfaces by means of a rotating abrasive wheel. You perform two types of grinding in a machine shop: hand and precision. Hand grinding is holding the wheel to the work or the work to the wheel and grinding by hand manipulation. Grinding lathe tool bits, which we discussed in Chapter 5 of Volume 1, is an example of hand grinding. In this chapter, we are mainly concerned with precision grinding. We will discuss such basic grinding matters as characteristics, markings, and selection of grinding wheels; cylindrical and special grinding operations; cutting-tool sharpening operations; and grinding machine attachments and maintenance.

3-1. Characteristics and Markings of Grinding Wheels

You can do a wide variety of work with a few general purpose grinding wheels. It has been estimated that there are 12,000 possible combinations of abrasive, bond, grade, and grain size (grit) for every wheel. It is, therefore, more economical in most machine shops to do grinding work with a relatively small number of general-purpose wheels. In this section, we will discuss the characteristics of the various materials used in grinding wheels and the meaning of the common grinding wheel markings.

425. List the various materials used in grinding wheels and give characteristics of each.

Grinding wheels are made of two different types of materials, abrasive and bond, with different kinds or grades for each material. You must know the characteristics of these materials in order to select the proper wheel for a particular job.

Abrasives. The abrasive grains are the cutting tools of a grinding wheel. They actually cut small pieces or chips off the work as the wheel rotates. The shape of each grain is irregular with several sharp cutting edges. When these edges grow dull, the forces acting on the wheel tend to fracture the abrasive grains and produce new cutting edges.

Most grinding wheels are made of silicon carbide or aluminum oxide, both of which are artificial (manufactured) abrasives. Silicon carbide is extremely hard but brittle. Aluminum oxide is slightly softer, but is tougher than silicon carbide. It dulls more quickly, but it does not fracture easily and is therefore better suited for grinding materials of relatively high tensile strength: carbon steels, high-speed steels, hard bronze, etc. Silicon carbide is best suited for materials of low tensile strength: cemented carbides, extremely hard alloys, marble, etc.

Bond. The abrasive particles in a grinding wheel are held in place by the bonding agent. The percentage of bond in the wheel determines to great extend, the "hardness" or "grade" of the wheel. The greater the percentage and strength of the bond, the harder the grinding wheel will be. "Hard" wheels retain the cutting grains longer while "soft" wheels release the grains quickly. If a grinding wheel is "too hard" for the job, it will glaze because the bond prevents dulled abrasive particles from being released so that new grains can be exposed for cutting. Besides controlling hardness and holding the abrasive, the bond also provides the proper safety factor at running speed. It holds the wheel together while centrifugal force is trying to tear it apart.

There are several kinds of bonds used in grinding wheels, but the most common kinds are vitrified, silicate, shellac, resinoid, and rubber.

Vitrified. A vast majority of grinding wheels have a vitrified bond. Vitrified bonded wheels are uneffected by heat or cold and can be made in a greater range of hardness than any other bond. They adapt to practically all types of grinding with one notable exception: if the wheel is not thick enough, it does not withstand side pressure as in the case of thin cutoff wheels.

Silicate. Silicate bond releases the abrasive grains more readily than vitrified bond. Silicate bonded wheels are well suited for grinding operations where heat generated by the cutting action must be kept to a minimum, such as in the grinding of edged cutting tools.

Shellac. Shellac bond produces a high finish, but it is not suited for heavy-duty grinding. Thin cutoff wheels are sometimes made with a shellac bond because it provides a fast, cool cutting action.

Resinoid. Resinoid bond is strong and flexible and is widely used in snagging wheels (for grinding irregularities from rough castings), which operate at 9,500 surface feet per minute (sfpm). If is also used in cutoff wheels.

Rubber. In rubber bonded wheels, pure rubber is mixed with sulfur. It is extremely flexible at operating speeds and permits the manufacture of grinding wheels as thin as 0.006 inch for slitting pin-point nibs. Most abrasive cutoff machine wheels have a rubber bond.

Exercises (425):

1. What two types of materials are grinding wheels composed of?

2. How are dulled cutting edges on abrasive grains in grinding wheels replaced by sharp ones?

3. State the difference between silicon carbide abrasive and aluminum oxide abrasive.

4. What is the purpose of the bond in a grinding wheel?

5. What is the most commonly used bond?

6. Give the characteristic of silicate bond that makes it especially well suited for use in wheels for cutter sharpening.

7. Why are rubber bonded wheels especially useful as abrasive cutoff wheels?

426. Interpret grinding wheel markings.

Markings. Every grinding wheel is marked by the manufacturer with a stencil or a small tag. The manufacturers have worked out a standard system of markings, shown in figure 3-1. The figure is self-explanatory and you should study it carefully. Note the information contained in the various positions:

(1) Kind of abrasive.
(2) Grain size.
(3) Grade.
(4) Structure.
(5) Bond.
(6) Manufacturer's record symbol.

For an example, let us use a wheel marked A60-L6-V11. The A refers to the abrasive, which is aluminum oxide. The 60 represents the grain size or grit size. Grain size represents the number of openings per linear inch in the screen through which the grains are sized before being mixed with the bonding agent. Generally speaking, coarse grit sizes cut away heavier chips and, as a result, leave a rougher surface on the work. Fine grit or grain cuts finer chips and produces a smoother finish.

The letter "L" in our example refers to the grade or the degree of hardness; as we stated in the last segment, the more of a particular kind of bond present in a wheel, the harder the grade of the wheel.

The "6" refers to the structure of the wheel. The structure of a wheel is the relationship of the abrasive grain and bonding agent to the number and size of the spaces around them. The individual grains and the surrounding bond material fill the entire volume of the grinding wheel; the resulting open spaces are required for heat dissipation, coolant application, and particularly for the temporary storage of chips. Wheels with coarse grains, which cut thicker chips, must have greater spacing than fine grain wheels, which cut very small chips. A wide spacing reduces the number of grains that contact the work surface within a given advance distance, and therefore it produces a coarser finish.

The "V" in the example refers to the bond, which in this case is vitrified. The "11" is a manufacturer's code for record purposes and its use is optional. At any rate, it will seldom be of any significance to you as far as choosing the right wheel for a particular job.

Exercises (426):

1. The grinding wheel number 50-C80-E10-S32 is broken down into sections in the left column below. Match the most appropriate meaning from the right column with each number in the left column. Not all meanings will be used.

____	1.	50	a.	Manufacturer's symbol designating exact kind of abrasive.
____	2.	C		
____	3.	80	b.	Grade—soft.
____	4.	E	c.	Bond type—vitrified.
____	5.	10	d.	Structure—dense.
____	6.	S	e.	Grade—medium hard.
____	7.	32	f.	Grain size—coarse.
			g.	Bond type—silicate.
			h.	Grain size—fine.
			i.	Structure—open.
			j.	Abrasive type—silicon carbide.
			k.	Manufacturer's record symbol.

3-2. Selection and Preparation of Grinding Wheels

In this section we will examine the factors to consider in selecting, inspecting, and balancing a grinding wheel, as well as the procedures for mounting, dressing, and truing wheels.

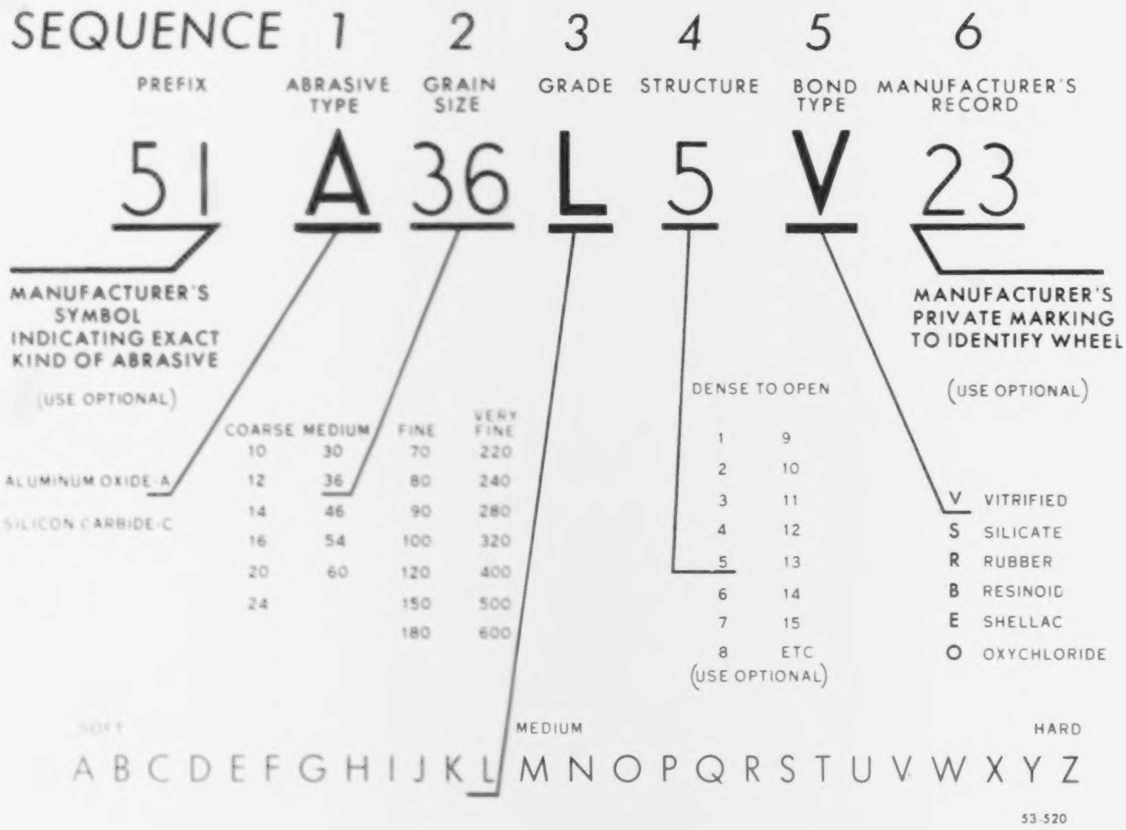

SEQUENCE 1 2 3 4 5 6
PREFIX
ABRASIVE TYPE
GRAIN SIZE
GRADE
STRUCTURE
BOND TYPE
MANUFACTURER'S RECORD
51 A 36 L 5 V 23
MANUFACTURER'S SYMBOL INDICATING EXACT KIND OF ABRASIVE
(USE OPTIONAL)
MANUFACTURER'S PRIVATE MARKING TO IDENTIFY WHEEL
(USE OPTIONAL)
ALUMINUM OXIDE-A
SILICON CARBIDE-C
COARSE 10 12 14 16 20 24
MEDIUM 30 36 46 54 60
FINE 70 80 90 100 120 150 180
VERY FINE 220 240 280 320 400 500 600
DENSE TO OPEN
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 ETC
(USE OPTIONAL)
V VITRIFIED
S SILICATE
R RUBBER
B RESINOID
E SHELLAC
O OXYCHLORIDE
SOFT
MEDIUM
HARD
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
53-520

Figure 3-1. Grinding wheel markings.

427. Point out the factors that influence the selection of a grinding wheel and explain selected inspection and balancing procedures.

Selection. There are so many different grinding wheels available that it is possible to use exactly the right wheel for each job you do. However, that isn't practical, because you would have to have hundreds of grinding wheels on hand in the shop. Most Air Force shops are small and must rely on a dozen or so general-purpose wheels for grinding operations. For that reason, you must consider several factors when selecting a grinding wheel: the kind of material to be ground, the amount of stock to be removed, the accuracy and finish required, the area of contact between the wheel and the work, the nature of the operation, and the work and wheel speed.

The type of material to be ground usually determines whether you use a silicon carbide or an aluminum oxide abrasive. As we stated before, aluminum oxide is suitable for grinding most steels including high-speed steels, and silicon carbide is best suited for grinding cemented carbide tools and extremely hard alloys.

In choosing the proper grain size, consider both the material to be ground, the amount of stock to be removed, and the area of contact. Fine grain sizes are best suited for hard and brittle materials; but if fast cutting rather than a fine finish is desired, a coarser grain is better. Also, the heavier the cut (which increases the area of contact as shown in fig. 3-2), the coarser the grain size should be.

The grade of the wheel that you choose depends on nearly all of the facators. Generally, hard wheels are used on soft materials and soft wheels are used on hard materials. However, as the size of the area of contact increases, the softer the wheel should be. Also, the higher the surface feet per minute (sfpm), the harder the wheel should be.

Structure also depends on several factors. Generally, dense (or close spacing) structures should be used on hard and brittle materials and open (or wide spacing) should be used on soft ductile materials. But wider spacing is better for rapid stock removal while a closer spacing produces a finer finish. Also, as the area of contact increases, so should the spacing.

Bond selection is usually not much of a problem. Vitrified bond is suitable for nearly any type of grinding that you may encounter in an Air Force shop. As we stated previously, there is one big exception; thin, cutoff wheels should have a rubber or resinoid bond.

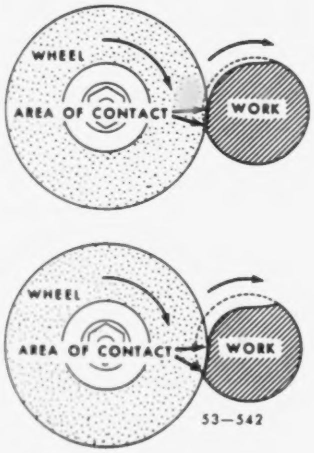


Figure 3-2. Area of contact.

The nature of the work usually dictates the shape of the wheel you will use. For instance, a straight wheel is commonly used for straight cylindrical grinding and a flaring cup wheel is used for sharpening certain types of cutters and reamers. Figure 3-3 shows the standard grinding wheel shapes.

Inspection. When you receive a wheel in the shop or remove it from storage, you should inspect it closely for damage and cracks. Check a small wheel by suspending it on one finger or with a piece of string. Tap it gently with a light nonmetallic instrument, such as the handle of a screwdriver, as shown in figure 3-4. Check a larger wheel by striking it with a wooden mallet. If the wheel does not emit a clear ring, examine it for cracks, and discard the wheel if it is cracked. All wheels do not produce the same tone when they are rung. A low tone does not necessarily indicate a cracked wheel. Wheels are often filled with various resins and greases to modify their cutting action, and resin or grease deadens the tone. Vitrified and silicate wheels emit a clear metallic ring. Resinoid-, rubber-, and shallac-bonded wheels emit a tone that is less clear. You can readily identify the sound of a cracked wheel.

Balancing. A grinding wheel under 12 inches in diameter seldom needs balancing. Larger wheels, especially those that are to be used in precision grinding, must be balanced. To balance a wheel, you mount it on an arbor and let it slowly revolve on a balancing stand, as shown in figure 3-5. The wheel will come to rest with the heaviest part down. You balance the wheel by shifting the position of the weights, either two or four in number, in a circular groove cut in the wheel mount bushing, as shown in figure 3-6. The weights are secured by a jam screw. If a wheel does not have weights, you can balance it by carefully chiseling out some of the wheel next to the bushing and filling the space with lead. After mounting the wheel, recheck the balance with the wheel rotating. Do not permit a wheel with which you perform wet grinding to remain stationary with a portion of the wheel immersed in the coolant. The wheel will absorb coolant in one area and be thrown out of balance. Also, for the same reason, do not permit coolant to flow on a stationary wheel. After mounting a wheel, stand to one side and let it run at full operating speed for at least 1 minute before using it.

NOTE: A wheel can fly apart. ALWAYS wear eye protection when you are grinding and stand to one side to avoid possible injury. Your eyesight is not expendable!

Exercises (427):

1. What factor usually determines whether you should use a silicon carbide wheel or an aluminum oxide wheel?
2. What two factors normally require you to choose a softer wheel?
3. What type of grinding operation always requires a bond *other than* vitrified?
4. How should you check a grinding wheel for cracks?
5. If a grinding wheel mount bushing does not have weights for balancing, how can you balance it?

428. Explain specified steps in wheel mounting, dressing, and truing.

Mounting. You mount a grinding wheel on the wheel spindle by means of wheel flanges or a collet. Power is transmitted through the flange or collect to the wheel. Figure 3-7 shows a flange mounting and figure 3-8 shows a collet mounting. Tighten the wheel between the flanges, or with the collet, enough to prevent wheel slippage and to transmit the driving torque. Do not tighten enough to crush the wheel. The safety guard should cover from one-half to three-quarters of the wheel diameter. The wheel guard should not expose more of the upper portion of the wheel than is required.

In flange mounting, you mount the wheel directly on the wheel spindle. There is a flange on each side of the wheel. These flanges must be equal in diameter and the center portion must be relieved, as illustrated in figure 3-7. The outer portion of the flanges provide the bearing surface. The diameter of a flange should be about one-third of the diameter of the wheel. Some

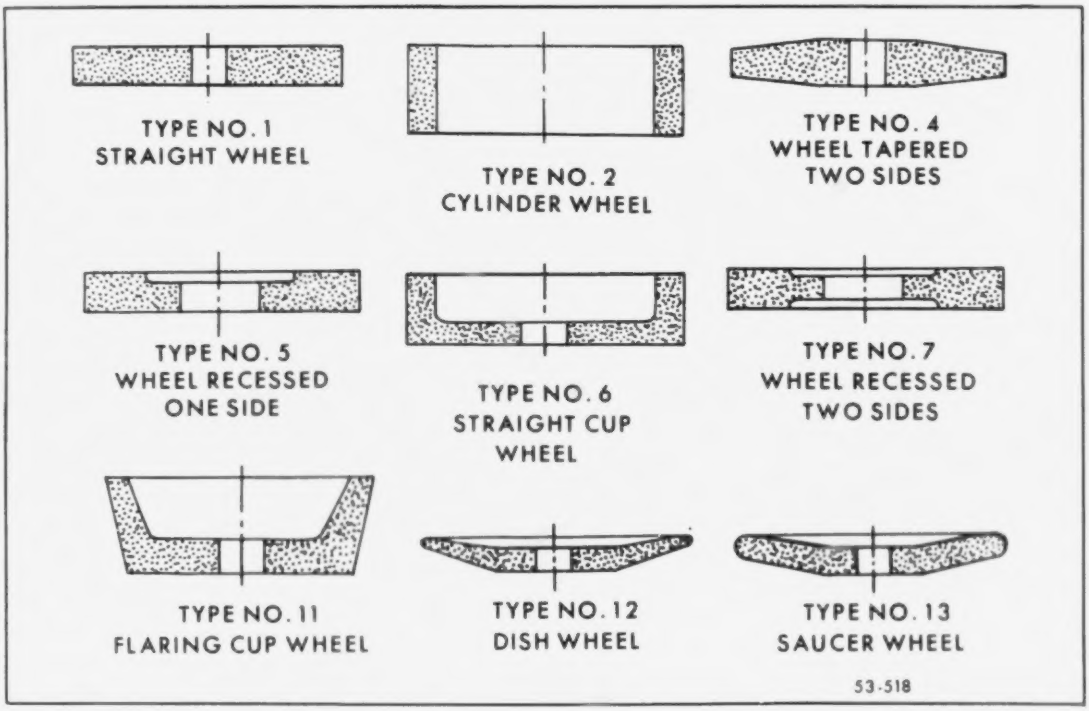

TYPE NO. 1
STRAIGHT WHEEL
TYPE NO. 2
CYLINDER WHEEL
TYPE NO. 4
WHEEL TAPERED
TWO SIDES
TYPE NO. 5
WHEEL RECESSED
ONE SIDE
TYPE NO. 6
STRAIGHT CUP
WHEEL
TYPE NO. 7
WHEEL RECESSED
TWO SIDES
TYPE NO. 11
FLARING CUP WHEEL
TYPE NO. 12
DISH WHEEL
TYPE NO. 13
SAUCER WHEEL
53-518

Figure 3-3. Standard grinding wheel shapes.

flanges are keyed to the spindle shaft. Others are pressed on the shaft. Insert a paper blotter, no thicker than .025 inch and no smaller than the flange diameter, between each flange and the wheel. Hold the spindle to prevent it from turning and tighten the spindle nut against the outer flange just enough to hold the wheel firmly.

Some grinding wheels are designed for mounting on a collet, as shown in figure 3-8. Small screws that pass through the bore of this type of wheel tighten the flanges of the collet against the wheel. Tighten one screw and then the one directly opposite, etc., to equalize the pressure against the wheel. You can mount the wheel on the collet with the collet either off or on the spindle. If the collet is already in place, it is easier to follow the latter practice. Otherwise, it is necessary to remove the collet from the spindle with a puller.

Dressing and Truing. As you may remember from Volume 2, a grinding wheel is *dressed* to improve or alter the cutting action of the wheel. The wheel is *trued* to restore a concentric surface to the wheel cutting face. You can expect a grinding wheel to perform efficiently only if it is properly dressed and trued. Within limits, a grinding wheel is self-sharpening. The forces acting at the point of contact tend to fracture and dislodge the dulled abrasive grains. This action results in new and sharp cutting grains contacting the work. In time, however, a grinding wheel needs dressing in order to clean out the metal-clogged pores. There are several types of dressing and truing tools, shown in figure 3-9.

Mechanical dresser. The hand-held Huntington mechanical dresser has alternate pointed and solid discs, which are loosely mounted on a pin. Use this dresser to dress coarse-grit wheels and wheels used in hand grinding. This type is the most efficient in picking the metal particles out of the wheel without causing a big loss of abrasive. You do not need to use a coolant.

Abrasive stick dresser. The abrasive stick dresser comes in two shapes: square, for hand use, and round,

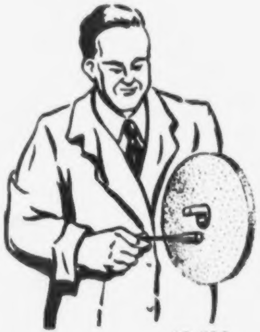


Figure 3-4. Checking for cracks.

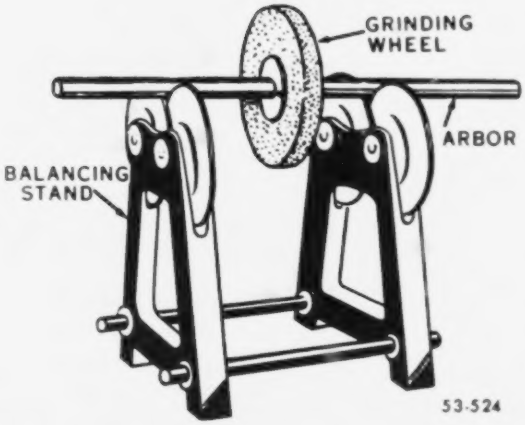


Figure 3-5. Wheel balancing stands.

for mechanical use. It is often used instead of the more expensive diamond dresser for dressing shaped and form wheels. It is also used for general grinding wheel dressing.

Abrasive wheel dresser. The abrasive wheel dresser is a bonded silicon carbide wheel that is fastened to the machine table at a slight angle to the grinding wheel and driven by contact with the wheel. The dresser produces a smooth, clean-cutting face that leaves no dressing marks on the work. You do not usually need to use a coolant.

Diamond dresser. The diamond dresser is the most efficient for truing wheels used for precision grinding where accuracy and high finish are required. A dresser may have a single diamond or multiple diamonds mounted in the end of a round steel shank. Inspect the diamond point frequently for wear. It is the only usable part of the diamond, and if it is worn away, it cannot dress the wheel properly. You should slant the diamond 3° to 15° in the direction of rotation, as shown in figure 3-9 (insert), to prevent chatter and gouging. Rotate the diamond slightly in its holder between dressing operations to keep it sharp. A dull diamond presses the wheel cuttings into the bond pores and loads the face of the wheel, which in effect increases the hardness of the wheel.

When you use a diamond dresser to dress or true a grinding wheel, the wheel should be turning at, or slightly less than, normal operating speed—*never* at a higher speed. For wet grinding, flood the wheel with coolant when you dress or true it. For dry grinding, the wheel should be dressed dry. The whole dressing operations should simulate the grinding operation as much as possible. Whenever possible, hold the dresser by some mechanical device. It is a good idea to round off wheel edges with a handstone after dressing to prevent chipping the wheel edges. This is especially true of a fine finishing wheel. You do not round off the edges if the work requires sharp corners. The grinding wheel usually wears more on the edges, leaving a high spot towards the center. When you start the dressing or truing operation, be certain that the point of the dressing tool touches the highest spot of the wheel first, to prevent the point from digging in.

Feed the dresser tool point progressively, .001 inch at a time into the wheel, until the sound indicates that the wheel is perfectly true. The rate at which you move the point across the face of the wheel depends upon the grain and the grade of the wheel and the finish desired. A slow feed gives the wheel a fine finish, but if the feed is too slow, the wheel may glaze. A fast feed makes the wheel free cutting, but if the feed is too fast, you may leave dresser toolmarks on the wheel. You can determine the correct feed only by trial, but always maintain a *uniform* rate of feed during any one pass.

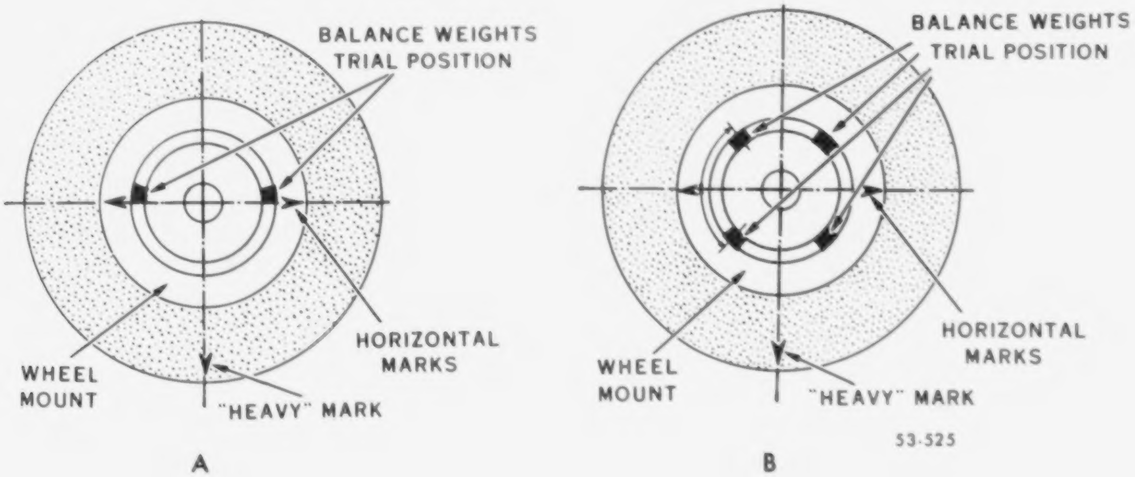


Figure 3-6. Use of balance weights.

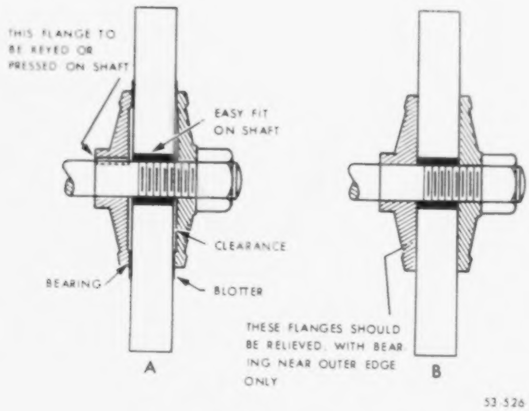

THIS FLANGE TO BE KEYED OR PRESSED ON SHAFT
EASY FIT ON SHAFT
CLEARANCE
BEARING
BLOTTER
THESE FLANGES SHOULD BE RELIEVED, WITH BEARING NEAR OUTER EDGE ONLY
A
B
53-526

Figure 3-7. Flange mounting.

Exercises (428):

1. How much of the grinding wheel diameter should be covered by the mounting flanges?

2. List the steps involved in mounting a flange-mounted wheel.

3. When you are mounting a collet-mounted wheel, what should you remember about tightening the clamping screws?

4. What is the difference between dressing a grinding wheel and truing it?

5. What is the most efficient grinding wheel dresser?

6. What is the purpose of slanting the diamond dresser toward the direction of rotation?

7. What is the rule for using coolant during a wheel dressing operation with the diamond dresser?

8. You are dressing a grinding wheel with a sharp diamond dresser, but you notice that the wheel is glazing slightly. What is the probable reason?

3-3 Cylindrical Grinding Operations

In cylindrical grinding, the work is driven by a spindle while it is held in a chuck, on an arbor, or between centers. In this respect, cylindrical grinding is similar to a lathe-turning operation. In this section, we will explain the calculations for surface feet per minute, the work preparation procedures, the characteristics of the cylindrical grinding process, and the procedure for grinding a reamer and various tapers.

429. Given the needed data, calculate the correct surface foot speed in cylindrical grinding.

Spindle Speed. In grinding, the speed is expressed in surface feet per minute (sfpm), in other words, the number of feet of the circumference of either the spindle or the work that passes the point of contact in 1 minute. The sfpm requirement remains fairly constant as far as the diameter of the wheel is concerned, but changes for various grinding operations and shapes of wheels. For example, the maximum recommended sfpm for the vitrified straight, dish, and saucer wheels used for cylindrical grinding is 5,500 to 6,500. For face grinding, the maximum recommended sfpm is 5,000 to 6,000. For straight or taper cup wheels for grinding cutting tools, the maximum recommended sfpm is 4,500 to 6,000. Machinists' publications such as the *Machinery's Handbook* list the recommended sfpm for various types and shapes of grinding wheels.

Once you have determined the recommended sfpm, you must convert it to rpm and check it against the

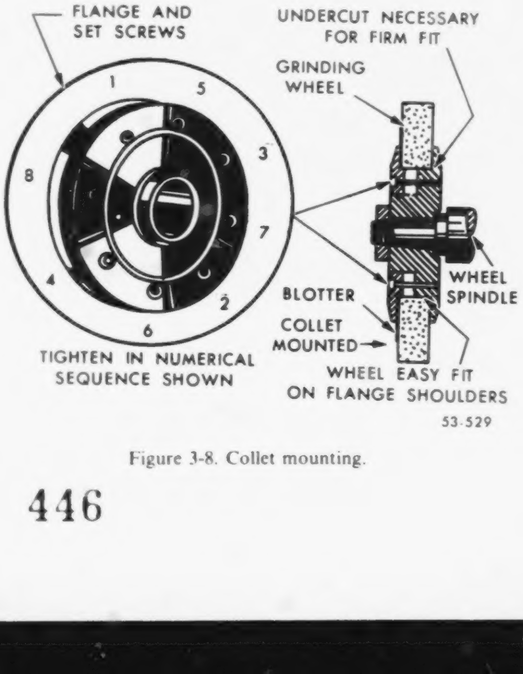

FLANGE AND SET SCREWS
UNDERCUT NECESSARY FOR FIRM FIT
GRINDING WHEEL
1
5
3
8
7
4
2
6
WHEEL SPINDLE
BLOTTER
COLLET MOUNTED
TIGHTEN IN NUMERICAL SEQUENCE SHOWN
WHEEL EASY FIT ON FLANGE SHOULDERS
53-529

Figure 3-8. Collet mounting.

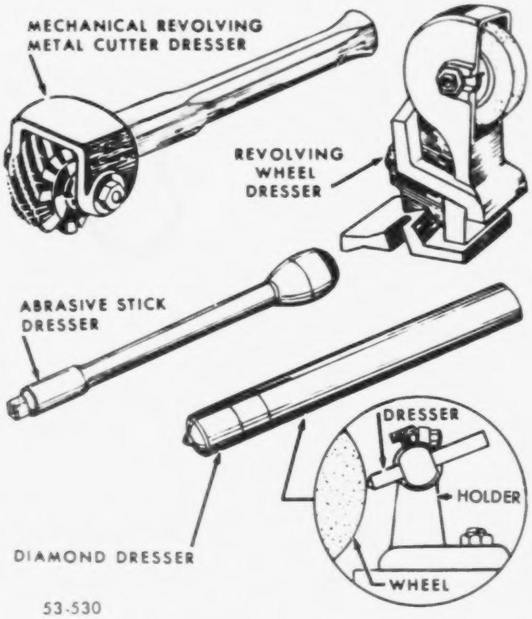


Figure 3-9. Dressing tools.

rpm of the machine. Since the spindle on most grinding machines operates at only one speed, you must vary the diameter of the grinding wheel to obtain the recommended sfpm.

NOTE: Be sure to check the maximum safe operating rpm on the grinding wheel. NEVER allow the wheel to operate a higher rpm than that marked on the wheel!

There are some simple formulas you can use to convert sfpm to rpm or rpm to sfpm. For example, to calculate the sfpm when you know the wheel diameter and the rpm of the spindle, you can use the following formula:

$$\text{sfpm} = \text{diameter of wheel} \times 0.2618 \times \text{rpm}$$

Suppose that you must grind a cylindrical piece of work with an 8-inch straight wheel on a spindle that rotates at 2,500 rpm:

$$\text{sfpm} = 8.00 \times 0.2618 \times 2{,}500$$
$$\text{sfpm} = 5{,}236$$

Since cylindrical grinding is done best at 5,500 to 6,500 sfpm, you find that your wheel and rpm combination is not the most efficient (although it would probably be adequate). By changing the diameter of the wheel when the rpm is fixed, you can come closer to the required sfpm:

$$\text{sfpm} = 9.00 \times 0.2{,}618 \times 2{,}500$$
$$\text{sfpm} = 5{,}890.5$$

In this case, a 9-inch-diameter wheel would be more efficient than the 8 inch wheel.

Now, suppose you want to find the proper spindle rpm for cylindrical grinding a part at 6,000 sfpm with an 8-inch wheel. You can calculate it by using the following formula:

$$\text{Spindle rpm} = \frac{\text{sfpm}}{\text{diameter of wheel} \times 0.2618}$$

$$\text{rpm} = \frac{6{,}000}{8 \times 0.2618}$$

$$\text{rpm} = 2{,}865 \text{ (rounded off to nearest whole number)}$$

Therefore, to use an 8-inch wheel at 6,000 sfpm, you need a spindle rpm of 2,865.

Work Speed. In addition to the wheel speed, you must also consider the work speed in such operations as cylindrical grinding because the work also rotates. Work speed is the speed at which the surface of the work rotates as it passes the point of contact with the wheel face. The recommended speed of the work (also given in sfpm) for grinding a plain cylinder is 60 to 100. You have to consider several factors when you select work speed: size and shape of the work, type of material, amount of stock to be removed, and desired finish. Irregular or out-of-balance work must be turned more slowly. If the grade of the grinding wheel is not exactly correct, you can improve the grinding efficiency by varying the work speed. You can change the work speed with the headstock pulley. Use the following formula to obtain the desired spindle rpm:

$$\text{rpm} = \frac{\text{sfpm}}{0.2618 \times \text{dia of work}}$$

Example: You want to obtain a work sfpm of 80 for grinding a steel shaft 1 inch in diameter. What is the desired spindle speed?

$$\text{rpm} = \frac{80}{0.2618 \times 1}$$

$$\text{rpm} = 305$$

In general, the faster the work speed, whether the operation is cylindrical or internal, the faster the wheel will wear. Recommended work speeds (sfpm) for various types of metal are listed in machinists' publications, such as the *Machinery's Handbook*.

Exercises (429):

1. How is speed designated in grinding operations?

447

2. You must cylindrically grind a part on a grinding machine with a 10-inch wheel and an rpm of 2.250. What will the sfpm be?

3. If the calculated sfpm in problem 2 was well under the recommended sfpm for the operation, how could you increase it without changing the spindle rpm?

4. Suppose you want to grind a part with a 9-inch wheel and a 6,000 sfpm. What spindle rpm would give the required sfpm?

5. If you want to obtain a work sfpm of 70 with a 2-inch-diameter shaft to be ground, at what rpm should the work turn?

430. Explain the purpose and selected characteristics of cylindrical grinding and describe some of the problems in preparing work for cylindrical grinding.

Cylindrical Grinding. As we mentioned previously, the work in cylindrical grinding is driven by a spindle while it is being held in a chuck, on an arbor, or between centers. There are many types and sizes of grinding machines in the Air Force on which cylindrical grinding can be done. In most cases, though, it is done on a tool and cutter grinder similar to the one shown in figure 3-10. On this machine, the table can be swiveled as much as 45° in either direction. Also, the wheelhead can be swiveled 360° about its base. You obtain the depth of cut by feeding the wheelhead toward the work. The cutting action proceeds along the length of the work by the longitudinal movement of the table.

Cylindrical grinding is done to remove the warpage caused by heat treatment, to reduce the work diameter to exact size, and to improve the finish. The work can be held and rotated by mounting it:

a. Between centers and driving it with a drive dog.
b. In a chuck and supporting it with a footstock.
c. On a live center and supporting it with a footstock.
d. On a faceplate.

The revolving grinding wheel provides the cutting action that takes place at the area of contact, as shown in figure 3-2. The area of contact varies when the dimensions of the wheel or the work are increased or decreased and when the depth of cut is increased or decreased. The wheel and the work are usually set to revolve in opposite directions at the area of contact, as shown in figure 3-2, producing a shearing type of cutting action between the wheel and the work.

Work Preparation. Before you grind work held between centers, you must lap the center holes. Lapping the center holes insures precise limits for roundness, straightness, and concentricity and increases the life of the machine centers. Lapping removes the scale and distortion left by heat treating and corrects inaccurately or roughly drilled holes.

A few Air Force shops have center lapping machines, which greatly simplify the center lapping process, as shown in figure 3-11. You hold one end of the work on an adjustable center. By pulling down on a hand lever, you bring the rotating lapping stone into contact with the center hole. By changing the belt on the pulleys, you can obtain speeds of 720, 1,300, 2,400 and 4,500 rpm. You can move the work rest up and down on the ways to accommodate work up to a length of 36 inches. The maximum width that can be held is 10 inches. A diamond dressing device is mounted on the spindle bracket, and there is a micrometer adjustment for positioning the diamond dresser for each dressing cut. You perform the dressing operation by swinging the dresser into position and passing the diamond dresser across the lapping stone. When you are not using the dresser, it should be swung back 90° out of the way. Always dress the lapping stone with the spindle in the retracted position, never in the extended position. The lapping stone is a bonded abrasive wheel cemented on a 1/2-inch steel spindle. It should be dressed frequently. A loaded or blackened stone does not cut freely and generates excessive heat. Lapping stones are often treated with oil to improve their cutting action. Some shops, however, prefer to use untreated stones.

If your shop does not have a center lapping machine, you can lap the center holes in a lathe or drill press. To do this, you mount a round piece of hard wood, one end of which is turned to a point with a 60° angle, in a chuck. Cover the rotation pointed end of the wood with lapping compound and insert it into the center hole of the work. Be sure to lap the center hole at each end of the work.

Exercises (430):

1. In cylindrical grinding, how do you obtain the depth of cut?

2. What is the purpose of cylindrical grinding?

3. In what direction should the work rotate in relation to the grinding wheel?

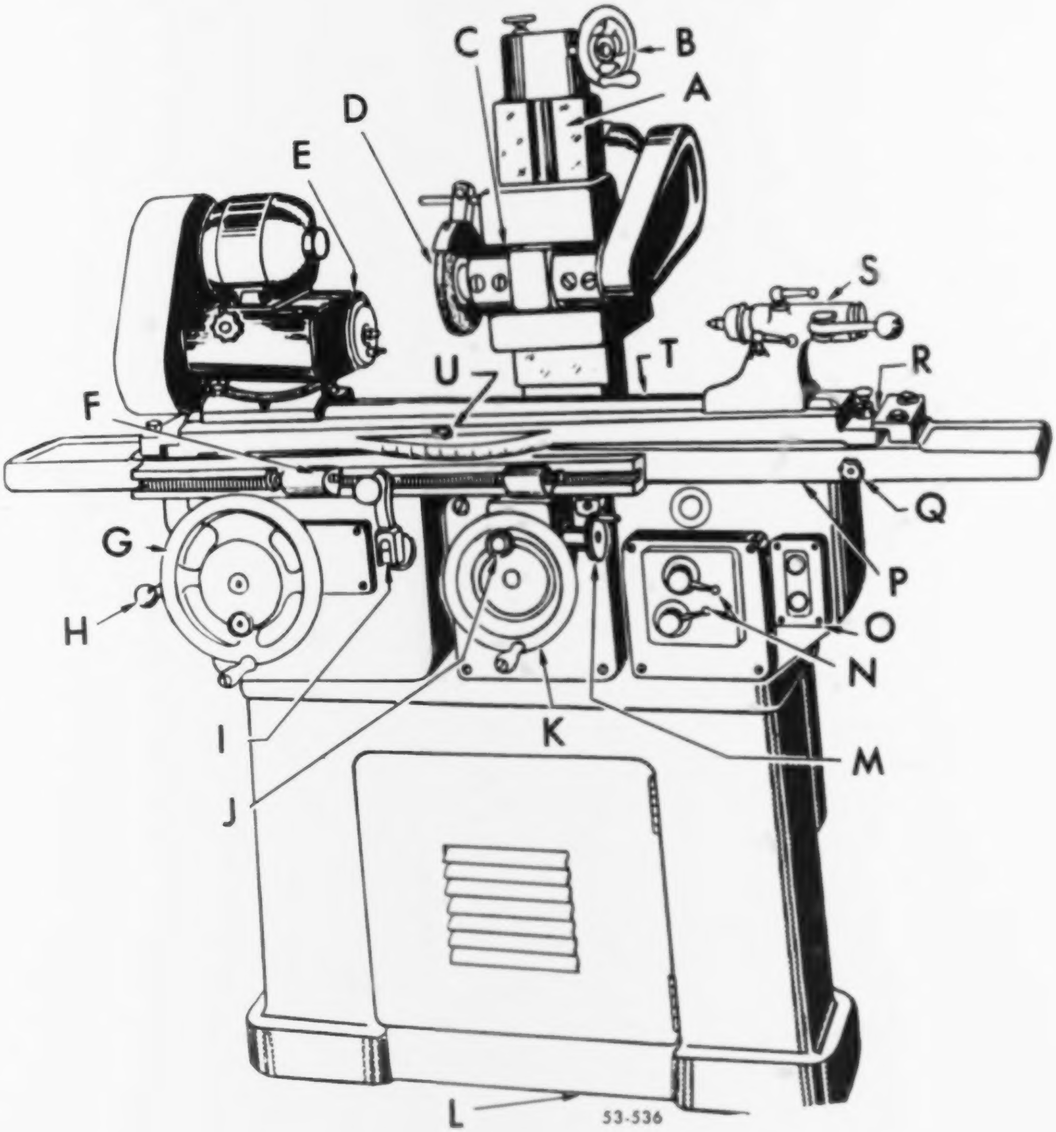


Figure 3-10. Typical universal tool and cutter grinder.

A Wheel slide ways
B Handwheel
C Spindle and wheel side
D Grinding wheel
E Headstock
F Table trip dogs
G Longitudinal handwheel
H Table traverse engaging lever
I Table traverse lever
J Fine crossfeed engagement knob
K Crossfeed handwheel
L Base
M Fine crossfeed handwheel
N Table traverse speed levers
O On-off switch
P Sliding table
Q Fine adjustment knob
R Taper scale
S Footstock
T Swivel table
U Clamp nut

4. What is the purpose of lapping center holesin work to be held between centers?

5. What are the undesirable results of using a loaded or blackened stone to lap workcenters?

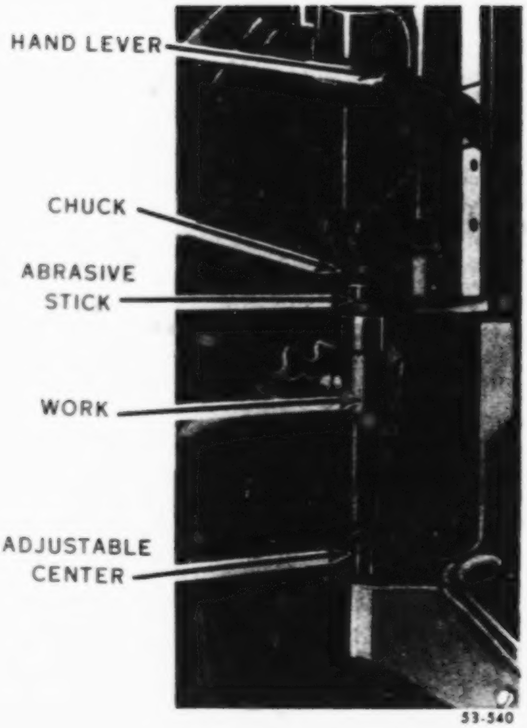


Figure 3-11. Lapping setup.

6. Explain how workcenters can be lapped in shops that do not have center lapping machines.

Describe the procedures for cylindrically grinding a hand reamer to a specified size on a tool and cutter grinder, and given the needed data, calculate the correct table traverse and table movement.

Cylindrically Grinding a Hand Reamer. Assume that you have the job of grinding a straight-fluted hand reamer to a specified size. After preparing the center holes, you could cylindrically grind this reamer on a universal tool and cutter grinder in the following manner: Select the proper wheel and mount it on the wheel flange assembly. Mount the wheel and wheel flange assembly on the wheelhead spindle and tighten the spindle nut. Place the wheel guards in position to cover the wheel adequately. Position the column and the table so that the graduations on the base of the column and on the front of the table indicate ZERO setting, and tighten the lock bolts. When the ZERO setting is indicated on the column and table, the axis of the wheelhead spindle shaft is parallel to the table. Place the diamond dresser and holder on the machine table with the diamond point properly positioned in relation to the wheel face, and tighten the lock bolt. Calculate the wheel speed and the work speed. Turn on the spindle drive motor to start the wheel rotating and let it run continuously through the grinding operation. Running the spindle and the wheel continuously keeps the spindle bearings and the grinding wheel in balance.

Turn on the coolant pump motor and position the nozzle to supply an adequate flow of coolant to the area of wheel contact. Place the splash guards in position to return the coolant to the reservoir tank. Turn the elevating handwheel to either raise or lower the wheelhead spindle until the lower cricket mark on the vertical slide corresponds with the cricket mark on the wheelhead. This aligns the center of the spindle and the wheel with the headstock center. Bring the wheel forward by turning the crossfeed handwheel until the revolving grinding wheel touches the diamond dresser lightly and dress and true the wheel. The depth of cut for dressing and truing should not exceed 0.001 inch for each pass across the face of the wheel. Move the wheel away from the diamond dresser to allow safe access to the table and remove the dresser, holder, and splash guards from the table.

Mount the headstock on the left end of the table. Align the graduated base of the headstock to the ZERO setting and secure the lock bolts. Attach the proper size of drive dog to the fluted end of the reamer. Place the reamer between the headstock and footstock centers with the end with the attached drive dog positioned on the headstock dead center. Do this in such a way that the dead center drive stud is in the crotch of the drive dog. Support the shank end of the reamer with the footstock center under spring tension. Secure the footstock to the machine table. Position the table trip dogs to allow minimum table traverse. The wheel should run off the shank end of the reamer into the gap provided by the footstock half center. Not more than one-half the wheel width should run off the shank into the undercut between the shank and the flutes. Bring the wheel to within approximately 1/8 inch of the reamer shank, and engage the work head clutch to revolve the reamer. The grinding wheel and the reamer should be revolving in opposite directions at the area of contact, as shown in figure 3-2.

Pick up the cut by hand manipulation of the wheel crossfeed and the table traverse. If any warpage is evident from heat treatment, pick up the cut at the highest point of warp. Place the splash guards in position to return the coolant to the reservoir tank. Calculate the table traverse feed for roughing, and set the table traverse speed levers to correspond as closely as possible to these calculations. Machinist publications list the recommended table traverse rate in fractions of the wheel width per work revolution. For excample, the recommended traverse rate for annealed steels is 1/2 for rough grinding and 1/6 for finishing; for hardened steels, the recommended rate is 1/4 for rough grinding and 1/8 for finishing. In most cases, you will probably have to convert these fractional recommendations to feet per minute before you can set the table traverse levers. Use the following formula:

table traverse = (width of wheel × fraction for finish × work rpm) ÷ 12

Example: You are using a 1-inch-wide wheel to rough grind a hardened steel cylinder with a work rpm of 300. What should the table traverse rate be?

table traverse = (75) ÷ 12
table traverse = 6.25 fpm

After you have completed your calculations and set the machine for the proper traverse rate, turn on the table traverse power feed and grind the shank of the reamer, using light depths of cut until you have a clean ground surface from end to end. Stop the table traverse with the wheel positioned off the shank in the gap in the half center of the footstock. Remove the reamer from between the centers. Use an outside micrometer with a vernier scale to measure the shank on each end for any taper present. Adjust for taper by loosening the five locking bolts on the table, and swivel the table by turning the fine adjustment screw.

You can determine the amount to swivel the table as follows: First, you must find the taper per inch (TPI) of the reamer. Take two measurements 1 inch apart. The difference is the TPI. Next, set up a dial indicator at one end of the table and set it on zero. Measure the distance from the swivel point of the table to the point where the indicator spindle touches the table and multiply that distance (in inches) by the TPI of the reamer. This gives you the amount of taper from the swivel point to the indicator. To correct the taper, you then adjust the table 1/2 the amount of the calculated taper. *Example:* You find that you have a taper of 0.002 TPI in the reamer. How much should you adjust the table to remove the taper?

First, select a point near the end of the table to set the dial indicator. In this case, suppose we select a point 10 inches from the swivel point of the table. Then:

0.002 (TPI) × 10 (distance from swivel to indicator) =
.020 total taper from swivel to indicator
.020 ÷ 2 = 0.010 inch

You should move the table 0.010 inch (indicator reading) to remove the taper. Be sure to move the table in the proper direction depending on the way the taper runs. CAUTION: Any time the table is swiveled, you must back the wheel away from the work and reestablish the cut, because moving the table toward the wheel also moves the work toward the wheel. This can produce too deep a depth of cut, breaking the wheel and destroying the workpiece.

Tighten the table lock bolts and rough grind the reamer shank to within 0.001 inch of the finished size. Remember that the body size of the shank of a hand reamer is 0.005 inch less than the nominal size of the reamer. This clearance enables the shank of the reamer to pass through the reamed hole without binding. Remove the reamer from between the centers and prepare the machine for finish grinding. Calculate the table traverse feed for finish grinding and position the traverse speed levers accordingly. Replace the reamer between the centers and pick up the cut for finish grinding. Finish grind the reamer shank to size, using light depths of cut. Remember that only 0.001 inch of metal remains to be removed. Move the wheelhead away from the work and remove the reamer from the centers. Remove the drive dog from the fluted end of the reamer and place it on the shank end.

Prepare the machine for rough grinding the flutes. Use the same procedures and calculations that you used to prepare the machine for rough grinding the shank. Place the reamer between the centers and position the table trip dogs to accommodate the length of the fluted end of the reamer. Rough grind the reamer flutes, using the same steps that you used to rough the reamer shank. Prepare the machine for finish grinding the reamer flutes, using the same procedures and calculations that you used to finish grind the reamer shank; *with one exception.* You should rotate the reamer in the opposite direction so that it will go in the *same* direction as the wheel at the point of contact. This procedure is used for grinding cutting edges (causing the heel of the tooth to contact the wheel first) because it produces clearance behind the cutting edge. Finish grind the reamer flutes to the designated size of the reamer, using the same procedures that you used for finish grinding the reamer shank.

Exercises (431):

1. How should the wheelhead and table be aligned for cylindrically grinding a straight fluted hand reamer?

2. How should the work be held and driven when you are grinding the shank of a hand reamer?

3. How is the recommended table traverse rate normally specified?

4. If you are using a 1.5-wide wheel to finish grind a hardened steel cylinder with a work rpm of 100, what should be the fpm of table movement?

5. After checking a grinding project between cuts, you find that there is a 0.0025 TPI in it. You therefore mount a dial indicator so that its spindle contacts the table 15 inches from the table swivel point. How much should you swivel the table to remove the taper?

6. What is the big difference between grinding procedures for grinding the reamer shank and those for grinding the flutes? Why?

432. Name some of the applications of conical taper grinding and internal grinding, and give some of the procedures and problems in these operations.

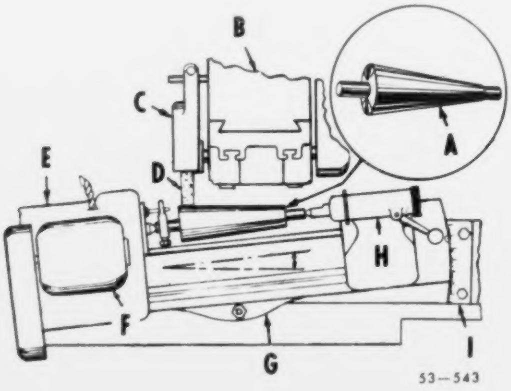
Taper Grinding. Taper or conical grinding applies to the grinding of round tapered surfaces, such as the shank and the point of a lathe center or the tapered portion of a taper plug gage. The reason that we refer to the operation as conical and not taper grinding is that flat work can also be ground with a taper. You can grind either external or internal work conically to any length.

You grind conical tapered work in a manner similar to the grinding of straight cylindrical work provided that the taper is not too steep or abrupt. After placing the work between the centers of the grinding machine, swivel the table to the required taper by means of the graduations on the end of the table. The correct work setup is illustrated in figure 3-12. This setup locates the axis of the work at an angle with the line of motion of the table. As the work moves across the face of the wheel, a taper is ground. The angle or taper depends upon how far you swivel the table from its central position. The correct angle or taper also depends directly upon the relation of the wheel to the work. In lathe work you will remember that, in order to turn a true taper, you must set the cutting tool exactly at center height or even with the axis of the work being machined. The grinding wheel axis must also be exactly at center height or even with the axis of the work to grind a conical taper. If you position the wheel above or below the center of the work, the taper will be different from the table setting indication.

You can usually grind steep tapers on a universal machine by swiveling the headstock to the desired angle of the taper, as shown in figure 3-13. Be sure that the axis of the grinding wheel is exactly at center height with the axis of the work. You can also grind internal conical tapers on the universal grinding machine with the aid of the internal grinding attachment, which we will discuss later. When you grind conical surfaces, you can dress and true the grinding wheel either before or after swiveling the table. The face of the wheel is always true and parallel to the ways regardless of the angle to which you swivel the table.

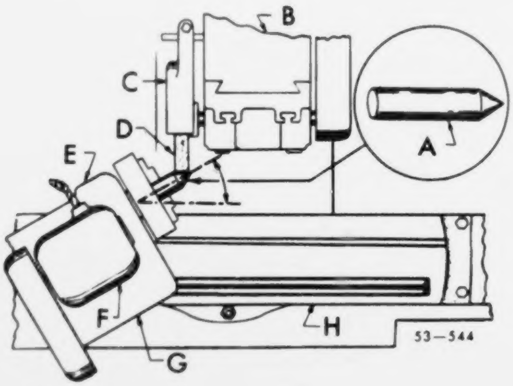
There are many methods of checking tapers. The two most common methods are to measure the taper per inch with a micrometer or to measure it with a gage. When you measure a taper with a tapered plug gage, use Prussian blue or white lead to check the contact of the surface being ground with the mating surface of the gage. You usually grind long tapers by setting the swivel table to correspond to the inches of taper per foot or to the desired number of degrees of taper specified for the work.

Internal Grinding. Internal grinding is grinding internal circular surfaces. The applications of this type of grinding are quite extensive. The range of hole sizes and types of work, as shown in figure 3-14, is limited only by the capacity of the machine. Internal



A Work
B Wheelhead
C Wheel guard
D Grinding wheel
E Headstock
F Motor
G Swivel table
H Tailstock
I Taper scale

Figure 3-12. Conical grinding setup.



A Work
B Wheelhead
C Wheel guard
D Grinding wheel
E Headstock
F Motor
G Swiveled headstock
H Table

Figure 3-13. Conical grinding setup for steep tapers.

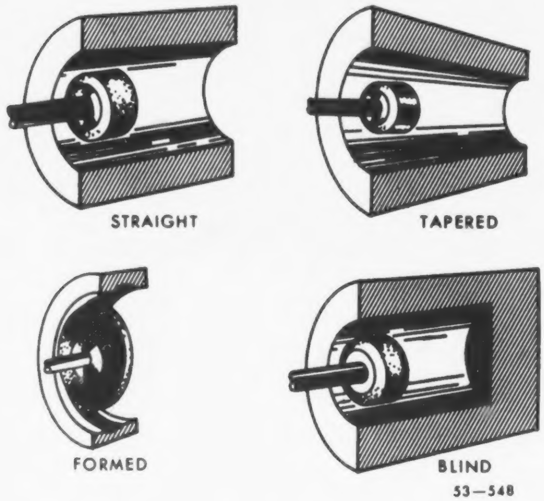


Figure 3-14. Typical internally ground surfaces.

grinding is a widely used method of finishing internal surfaces, because it is accurate and economical and produces a good surface. In many instances, this method of grinding has taken the place of reaming and boring holes. You will be called upon many times to finish a hole in a hardened metal part because the heat treating process caused a certain amount of distortion. You must grind the hole internally to secure an accurate diameter and a true surface. Some classes of internal grinding are done on a lathe with a tool post grinder, which we discussed in Volume 2. Internal grinding speeds and feeds are calculated in the same way as external cylindrical grinding.

Internal grinding is done on the universal tool and cutter grinder with the aid of an internal grinding attachment. Figure 3-15 shows a typical internal grinding attachment mounted on a grinding machine. Note that the belt and pulleys are exposed, though, during actual operation, this area should be covered with a guard.

Because small grinding wheels are used for internal grinding, the spindle (or quill as it is called) must be operated at a high speed to maintain the required sfpm. You increase the rpm by placing a large pulley on the machine wheelhead and a small pulley on the attachment. The usual ratio between the two pulleys is 3 to 1.

Most internal attachments come with several sizes of spindles (quills). Use the largest quill possible for the hole that you are grinding. The smaller quills tend to spring away from the work easily and produce taper and irregularities.

One condition that is more pronounced in internal grinding than in external is the larger area of contact. Large areas of contact usually cause the wheel to load and glaze quickly, which in turn causes vibration and produces poor surface finishes. Therefore, it is important to pay particular attention to the condition of the wheel during the grinding operation. Because of the tendency of the wheel to load in internal grinding, it is best to use either a coarser grain wheel to provide more chip clearance or a softer grade wheel that will break down more easily.

During the grinding operation, let the grinding wheel run out of the end of the hole for at least one-half the width of the wheel face but not more than two-thirds. If the wheel is allowed to clear the work each time the table reciprocates, it will grind a bell-mouthed hole because of spring in the quill.

Exercises (432):

1. Name some of the applications of conical taper grinding.
2. How should the work be aligned for grinding a long taper between centers?
3. If you were grinding a long conical taper between centers and, even though the table was swiveled the correct amount, the TPI is still not right, what is the probable cause of the trouble?
4. How can you grind steep tapers on a universal grinding machine?

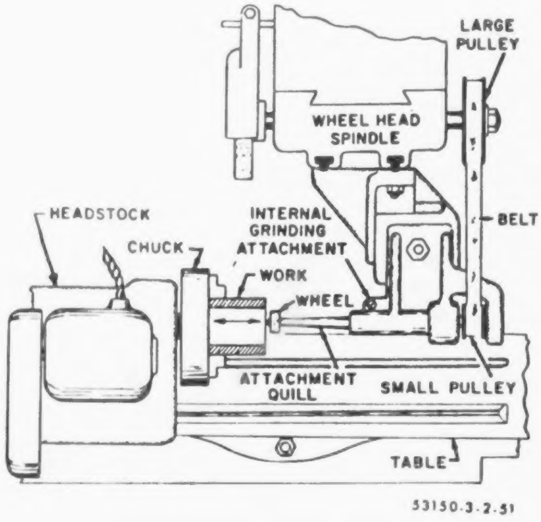


Figure 3-15. Internal grinding attachment.

5. Name some of the applications of internal grinding.

6. What must you use with the universal grinding machine to perform internal grinding?

7. What problems do the smaller wheels and the larger area of contact in internal grinding produce?

8. When you are performing internal grinding, why shouldn't you let the wheel come completely out of the hole as the table reciprocates?

3-4. Special Grinding Operations

In this section, we will discuss face grinding, including the grinding of shoulders and grooves, form grinding, and surface grinding.

433. Explain selected procedures in face grinding, shoulder and groove grinding, and form grinding.

Face Grinding. Face grinding is often necessary on heat-treated parts and hard parts to obtain the correct length and finish. In making the work setup, always make sure that the face to be ground is square with the axis of the work. If possible, do all the necessary grinding operations, such as cylindrical, shoulder, and face grinding, at one setting to insure maximum accuracy. There are three methods of face grinding: angular wheel, cup wheel, and straight wheel. You normally use the angular wheel method, shown in figure 3-16, when you grind two or more surfaces, such as a cylindrical surface, the shoulder, and the face. A disadvantage of the angular method is that the axis of the wheel spindle is not perpendicular to the face of the work.

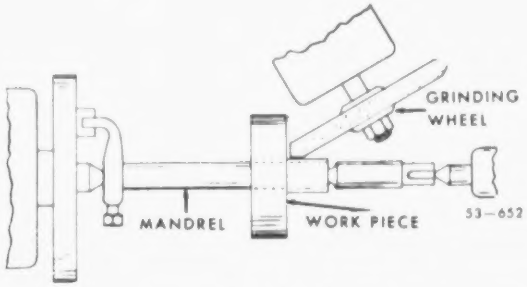


Figure 3-16. Setup for grinding a face, shoulder, or recess with an angular shaped wheel.

You can use the cup wheel method, shown in figure 3-17, for either external or internal face grinding by selecting a cup wheel of the proper size. The area of contact between the wheel and the face of the work is, as you can see, quite small. This is a desirable feature.

The straight wheel method, shown in figure 3-18, is seldom used in Air Force shops. This method is used for rough grinding only. Grinding with the side of the wheel is not efficient, since the area of contact is too large. If you must use this method, you can obtain better results by recessing the wheel.

Shoulders and grooves. The grinding of shoulders and grooves involves cylindrical pieces that have two or more diameters, radii, or fillets. The methods used for this type of grinding are essentially the same as described in face grinding except that, in plain face grinding, only one surface, the face, is ground. In grinding shoulders and grooves, there is usually more than one surface involved. Therefore, the cup wheel method is not as suitable as the straight wheel method, since the side of a cup wheel should not be used as a grinding face. You can sometimes perform these operations by swiveling the wheelhead and using an angular-faced wheel. You can also use a straight wheel with the side recessed to reduce the area of contact with the shoulder. Either of these methods assures a freer cutting action than would be possible with a straight-sided wheel. If you grind straight shoulders with the side of the wheel that is not recessed, as shown in figure 3-18, use a softer grade of wheel to obtain a freer cutting action on the shoulder.

If you must hold to close tolerances on radii or fillets, you will have to use a harder grade wheel with fine grit to prevent the rapid breakdown of the wheel face. Naturally, this reduces the rate of stock removal. When you use the straight wheel method to grind a shoulder, it is desirable to recess the side of the wheel that will grind the shoulder. You can recess a wheel, if a fine finish is required, with a diamond dresser. If you are not able to move the wheel in close enough to the table to permit the use of the diamond, you can use an abrasive stick and recess the wheel by hand. If a radius is required on the corner of the wheel, you can form it by using the radial attachment or the abrasive stick. If you use the abrasive stick, check the radius with a radius gage, after stopping the wheel.

When you use the angular wheel method to grind a shoulder, as shown in figure 3-16, swivel the wheelhead 30° to 45° off center. Both faces of the wheel must be at the same angle and of equal length. The horizontal face of the wheel grinds the diameter, and the vertical face of the wheel grinds the shoulder. If a radius is required at the shoulder, you will have to use the radial grinding attachment or the abrasive stick to obtain the correct radius. You must be very careful to prevent wheel breakdown at the point that grinds the shoulder. If you find it difficult to move the wheelhead crossfeed close enough to the table for the correct depth of cut, you can overcome this difficulty by using the extension spindle. Always use as narrow a wheel as possible. It

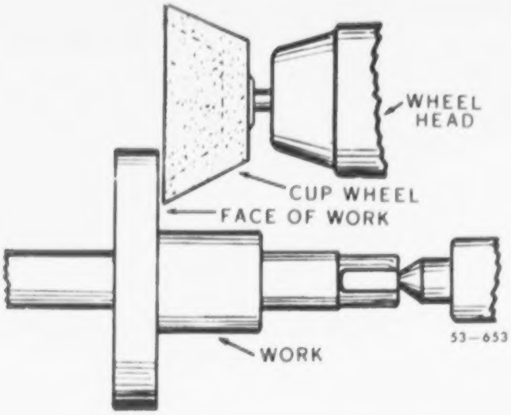


Figure 3-17. Face grinding with a cup wheel.

should be at least 7 inches in diameter, hard grade, and fine grain.

When possible, it is desirable to undercut or recess the work slightly at the shoulder during fabrication. However, some workpieces are so designed that undercutting them before they are hardened would weaken them or cause cracks to develop during heat treatment. You can grind such a shoulder or a groove by *plunge grinding,* which is straight-in feed in which no table traverse is involved. You can use plain straight-faced or form-faced wheels to produce any desired form on cylindrical work. The ability of a wheel to hold its form is more important than the rate of stock removal during this type of grinding. For this reason, a harder grade of wheel is usually required.

Form Grinding. Form grinding is performed in much the same manner as form turning on a lathe or form milling on a milling machine. The form to be ground on the surface is cut into the face of the wheel. This type of grinding should be limited to small parts because of the large surface contact of the wheel to the work. An example of this type of form grinding is the grinding of a convex surface. The wheel for grinding a convex surface is trued to a concave shape of the proper radius and the surface is then ground to the proper size. Make extremely light cuts to reduce the possibility of burning the work or causing it to develop grinding cracks. Form grinding can be done on the surface grinder or on a cylindrical grinding machine.

Exercises (433):

1. What are the three methods of face grinding?

2. Explain why the cup wheel method of face grinding is more desirable than the straight wheel method.

3. Why is the cup wheel method less desirable than the other two methods for grinding shoulders in conjunction with a cylindrical surface?

4. Explain the procedure for using the straight wheel method to grind a shoulder.

5. How should you grind a recess or groove next to a shoulder?

6. Explain the procedure for form grinding.

434. Describe the two types of horizontal spindle surface grinders and explain key procedures for grinding a hardened steel parallel on a reciprocating table surface grinder.

Surface Grinding. Surface grinding is the grinding of flat surfaces. In actual use, the surface is in either a horizontal, a vertical, or an angular position. You can compare surface grinding to machining a flat surface on a shaper if you remember that a shaper uses a single-point cutting tool and a grinder uses a grinding wheel. There are two types of horizontal spindle surface grinders—the reciprocating table type and the rotating table type.

Horizontal spindle surface grinders are designed for the efficient production of accurate flat surfaces where precision, fine finish, and rapid removal of stock are of equal importance. They are divided into two classes

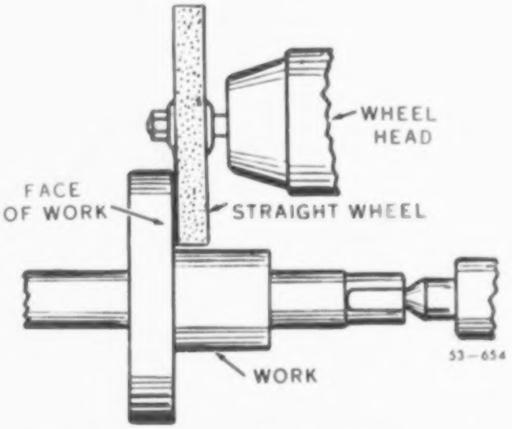


Figure 3-18. Setup for grinding a face, shoulder, or recess with a straight wheel.

according to table movement. On the reciprocating table type, you mount the work on a reciprocating table, which passes the work back and forth under the wheel face. Wheel feed takes place at each end of the table movement. Figure 3-19 illustrates surface grinding on a reciprocating table. On a rotating table type, you mount the work on a circular table, which rotates the work under the wheel face, as shown in figure 3-20. The wheel moves in a horizontal plane across the work from the outer to the inner circumference and back. You feed the work by moving the table upward into the wheel.

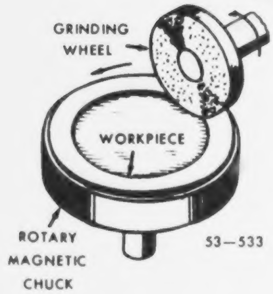


Figure 3-20. Rotating table.

Assume that you have a hardened steel parallel to grind to a specified size. You can perform this operation as follows: Mount the proper wheel on the wheel flange assembly. Mount the wheel and wheel flange assembly on the wheelhead spindle. Tighten the spindle and flange nuts. Place guards over the wheel. Mount the diamond dresser and holder, as shown in figure 3-21, on the magnetic chuck and turn the chuck switch to the ON position. (NOTE: Tilt the diamond in the direction of wheel rotation.) Position the wheel directly over the diamond. Start the wheel rotating and bring the wheel down until it touches the diamond. Turn on the coolant, and dress and true the wheel by using the hand crossfeed. Move the wheelhead assembly away from the table enough to allow safe and easy access to the chuck face. Position the magnetic chuck switch to the OFF position and remove the diamond and holder from the chuck. NOTE: Avoid sliding the part across the chuck face. Tip it slightly sideways and pick it up.

Clean the chuck face thoroughly to remove all abrasive residue. Place the parallel on the magnetic chuck, and shim if necessary. Turn the magnetic chuck switch to the ON position. Position the longitudinal trip dogs so that the wheel will run off the parallel at both ends. Position the transverse trip dogs so that the wheel will run off the sides of the parallel. Turn on the machine, the hydraulic system, and the coolant pump. Check the power feed and the wheelhead and table for wheel overrun and make any necessary adjustments. You can use the continuous power feed for these settings. Using the hand feed, position the wheel directly over the parallel and pick up the cut while the table is in motion. Position the coolant nozzle to supply an adequate volume of coolant to the wheel and the parallel.

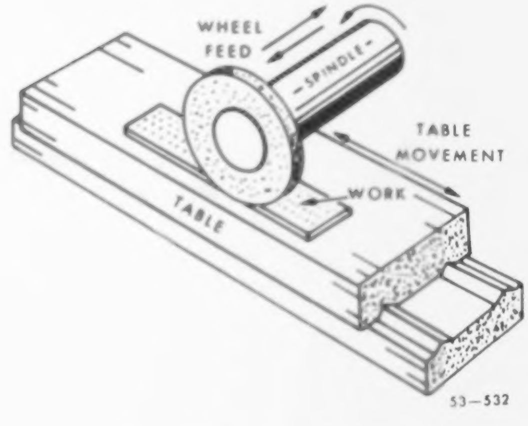


Figure 3-19. Reciprocating table.

Turn on the wheelhead power feed and rough grind the parallel. The downfeed depth of cut should not exceed 0.002 inch. If the wheel loads during rough grinding, repeat the dressing operation. Stop the table motion and move the wheelhead assembly away to allow safe access to the parallel. Turn the magnetic chuck switch to the OFF position and remove the parallel. Clean the chuck thoroughly. Replace the parallel in the same position on the chuck with the ground side down. Turn the magnetic chuck ON and rough grind the second side. Turn on wheelhead power feed and finish grind the side of the parallel. The downfeed depth of cut for finish grinding should not exceed 0.005 inch. Deburr the parallel to remove the rough edges and check all dimensions for accuracy.

Exercises (434):

1. Briefly describe the two types of horizontal spindle surface grinders.

2. Explain the procedure for dressing the grinding wheel on a reciprocating table surface grinder.

3. How should you determine where to place the table trip dogs when you are surface grinding a parallel?

4. Explain the procedure for picking up the cut when you are preparing to grind a parallel on the surface grinder.

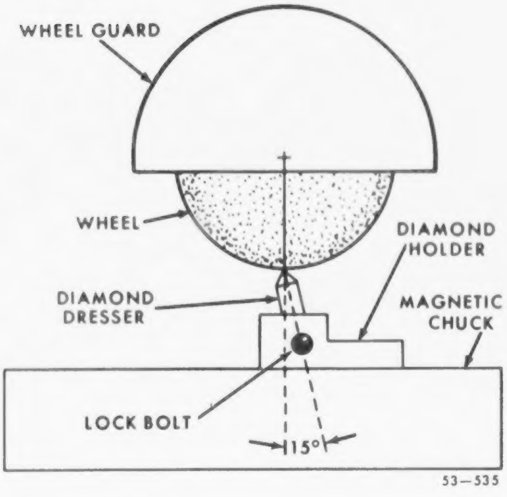


Figure 3-21. Surface grinder wheel dressing setup.

5. State the limits for the depth of cut for rough grinding on the surface grinder. For finish grinding.

3-5. Tool Sharpening Operations

The working efficiency of a cutter is determined largely by the keenness of its cutting edge. Therefore, it is important to sharpen a cutter at the first sign of dullness. A dull cutter not only leaves a poorly finished surface, but after its continued use, you have to grind away a large portion of the teeth to restore the cutting edge. If you maintain a cutter in good working condition by frequent sharpening, it always cuts rapidly and effectively. When such a cutter does need sharpening, you have to grind the teeth only a very small amount to insure a keen cutting edge. In this section we will discuss grinding cutters cylindrically, cutting tool clearance, grinding form cutters, grinding shell end mills, and grinding helical milling cutters.

435. State the purpose of grinding cutting tools cylindrically and point out some precautions to observe.

Grinding Cutters Cylindrically. Certain types of cutting tools, such as reamers and milling cutters, are ground cylindrically to remove warpage from heat treatment, to remove nicks, to obtain a specific diameter, or to produce a finish and a slight clearance on the cutting edges of the teeth. When you grind tools cylindrically, the work is rotated in the opposite direction from that ordinarily used in cylindrical grinding. If a clearance is desirable on the cutting edges, the wheel and the work should move in the same direction at the area of contact, as shown in figure 3-22. Mount the cutter so that the heel of the tooth strikes the wheel first. In theory, this will cause a slight spring between the work and the wheel, which in turn will cause the heel of the tooth to be ground slightly lower than the cutting edge. The clearance will vary in amount, depending upon the rigidity of the cutting tool being ground and the work setup. The work can be held for the cylindrical grinding operation in three ways: between centers, on a mandrel, or on a stub arbor mounted in the headstock spindle. You should normally select a medium grain and a medium grade grinding wheel for the cylindrical grinding of hardened steel and high-speed steel cutters.

After you have cylindrically ground a cutter or reamer to restore concentricity, you can use either of two methods to sharpen the cutting edges of the teeth and to provide extra clearance. These methods depend upon the rotation of the grinding wheel in relation to the cutting edge. Figure 3-23 illustrates these two methods of straight grinding wheel setup. In method A, the rotation is from the body of the tooth off the cutting edge. The wheel rotation holds the cutter on the tooth rest but will raise a burr on the cutting edge, which you must remove by stoning. This method has a tendency to draw the temper from the metal. In method B, the wheel rotation is from the cutting edge toward the body of the tooth. In this method, there is less danger of burning the tooth, but you must exercise great care in holding the cutter on the tooth rest. If the cutter turns while you are grinding the tooth, it will be ruined. Cup wheels, shown in figure 3-24, are also used extensively to grind cutters and reamers. You use cup wheels very much like straight wheels.

Exercises (435):

1. What is the purpose of cylindrically grinding milling cutters?

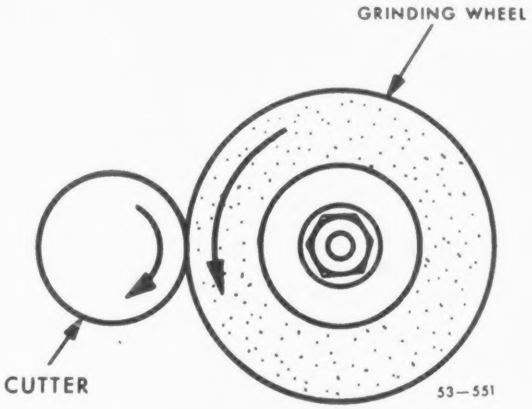


Figure 3-22. Wheel and cutter rotation for cylindrical grinding.

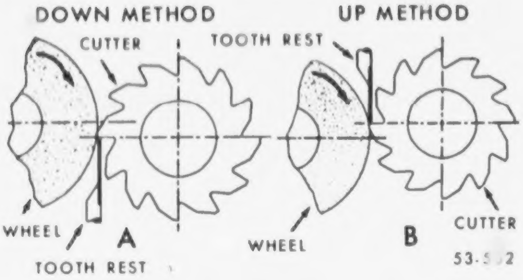


Figure 3-23. Cutter sharpening positions.

2. What is the object of mounting the cutter so that the heel of the cutter teeth strikes the grinding wheel first?

3. When you are sharpening cutter teeth with a straight wheel using the "up" method, what must you be especially careful of?

436. Explain the purpose, calculations, and procedures for grinding the clearance angles on various cutters.

Cutting Tool Clearance. Correct clearance back of the cutting edge of any tool is essential. With insufficient clearance, the teeth will drag, producing friction and slow cutting. Too much clearance produces chatter and dulls the teeth rapidly. The cutting edge must have strength, and the correct clearance will produce this strength. Figure 3-25 shows a typical cutter tooth and the various angles produced by grinding. A secondary clearance of 3° to 5° in addition to the angle of the land (depending upon the design of the cutter), produces a strong tooth and provides easy control of the width of the cutting land. The width should be 1/64 inch to 1/16 inch, depending upon the diameter of the cutting tool. When the cutting land becomes too wide from many sharpenings, you must grind a secondary clearance to restore the land width to its correct dimension. You produce the secondary clearance by locating the wheel, cutter, and tooth rest properly. There are several setup methods, depending upon the type of wheel used, the shape of the work, and the location of the tooth rest. The wheel may be either a plain straight wheel or a cup wheel. The work may be straight or tapered and may have straight or helical teeth. The tooth rest may be located on either the wheelhead or on the table. The ends of the tooth rest vary in shape for different cutters. When you use a straight wheel, the clearance angle depends upon the diameter of the wheel. When you use the cup wheel, the diameter of the cutter is the determining factor.

To determine the setting for a cutter when you use the straight wheel method, multiply the clearance angle of the cutter in degrees times the wheel diameter in inches times the constant 0.0088. The constant 0.0088 is derived from the distance of 1° on the circumference line of a 1-inch circle. The result is the amount, in thousandths of an inch, that you raise or lower the cutter and tooth rest to obtain the setting by multiplying the clearance angle in degrees times the cutter diameter in inches times the constant 0.0088.

Normally, the tooth rest is fastened to the table when you grind straight-toothed cutters. When you grind helical-toothed cutters mounted between centers, the tooth rest must be mounted on the wheelhead so that the work can revolve and follow the angle of helix on the teeth. You can calculate the distance to raise or lower the wheelhead or tooth rest by a formula which we will discuss in the next segment. It is given in machinists' publications, such as *Machinery's Handbook*, in charts from which you can obtain the recommended clearance angles for most cutters.

Exercises (436):

1. What is the object of grinding a primary (land) and secondary clearance on a milling cutter tooth?

2. What should the angle and width of land be for a medium diameter cutter to be used on low carbon steel?

3. What determines the type of setup needed for grinding clearances on a cutter?

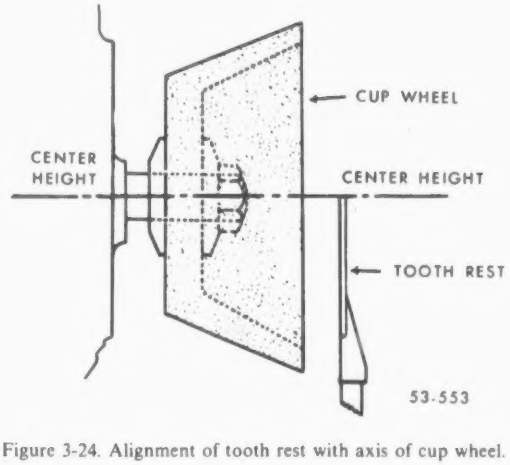


Figure 3-24. Alignment of tooth rest with axis of cup wheel.

Material	Clearance angle A (degrees)	Clearance angle B (degrees)	Width of Land D (inches)
Low carbon steel	5 to 7	3 to 5	
High carbon steel and tool steel	3 to 5	3 to 5	
Steel castings	5 to 7	3 to 5	
Cast iron	4 to 7	3 to 5	Small cutters 1/64
Cast brass	10 to 12	3 to 5	Medium cutters 1/32
Soft bronze	10 to 12	3 to 5	Large cutters 1/16
Medium bronze	6 to 7	3 to 5	
Hard bronze	4 to 5	3 to 5	
Copper	12 to 15	3 to 5	
Aluminum	10 to 12	3 to 5	

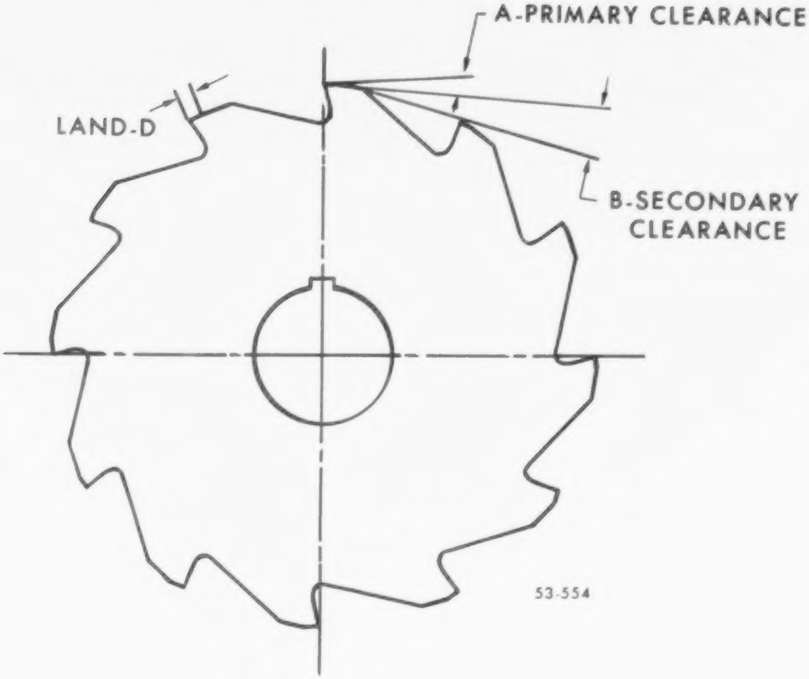


Figure 3-25. Recommended clearance angles.

4. In using the cup wheel method to grind 5° clearance angles on a 6-inch diameter plain milling cutter, how much should the cutter and tooth rest be lowered?

437. Given problems in the grinding of form cutters, shell end mills, and helical milling cutters, select the best solutions.

Grinding Form Cutters. Formed or eccentrically relieved cutters, such as gear cutters and convex and concave cutters, cannot be sharpened in the same way as the profile-type cutters. Form cutters have a definite shape that must be retained through many sharpenings. To retain this shape, you must grind the face of the tooth. Since you grind the face of the teeth with a radial rake, excessive positive or negative rake on formed cutter teeth changes their shape. "Radial rake" means that the faces of the teeth are in a plane passing through the axis of the cutter.

You may sharpen form cutters with the infeed type of form cutter attachment, but before you can grind a cutter by the infeed method, you may have to grind the back of the teeth so that the tooth width remains the same for each of the teeth. You can also mount the form cutter on a mandrel or a stub arbor and grind the cutting edges by using the index method in a universal head.

Grinding Shell End Mills. You sharpen shell end mills by mounting the cutter on a stub arbor or shell end mill arbor and placing the arbor in the universal attachment in the same manner that it is supported in the milling machine. Place a cup wheel, with either a straight or flaring cup, on the spindle and, with an abrasive stick, dress the cutting edge of the wheel. To prevent the end mill from dragging, the teeth are usually slightly tapered to the middle or center of the cutter. You make this taper by swiveling the universal head about 1/2° to 1°. In order to obtain the proper clearance angle on the teeth, swivel the head vertically to the prescribed clearance angle. The micrometer tooth rest is usually used in this sharpening operation because it is easily set to the proper height.

Grinding Helical Milling Cutters. You grind the helical milling cutter by mounting the cutter on the arbor or mandrel and placing it between the right- and left-hand footstock. Select and mount a cup wheel. Swivel it several degrees so that the back cutting edge of the wheel does not come in contact with the cutter being ground. Adjust the tooth rest to the proper height to achieve the desired clearance angle. This setting may be calculated with the following formula:

$$\text{Tooth rest setting} = 0.0088 \times \text{clearance angle} \times \text{dia. of cutter}$$

The cutter clearance may be found in machinists' publications, such as *Machinery's Handbook*.

The cutter should be held lightly against the tooth rest, with just enough pressure to maintain contact. When you use the "down" method, the grinding wheel aids in maintaining this pressure. Be careful to maintain contact with the tooth rest when you return the cutter to the starting point. If the cutter is not in contact with the tooth rest when it is returned to the starting point, you will damage the tooth. The cutter may be traversed across the wheel face by the movement of the table or by sliding on an arbor. The life of the cutter teeth depends on keeping the peripheral cutting edges concentric. When the teeth are out of round, the resulting pounding action soon breaks down the cutting edge, shortening the life of the cutter. This condition is due largely to the wearing of the grinding wheel during the sharpening operation. You can correct the out-of-round condition by an equalizing operation. The equalizing operation is simply grinding around the cutter, rotating the cutter 180°, and starting the second cut around the cutter on the tooth just opposite the first tooth. Use light cuts to reduce wheel wear. Repeat this operation until the cutter has been completely sharpened.

Exercises (437):

1. To sharpen formed cutters, where are they ground?

2. How should the teeth of a shell end mill be ground to prevent them from dragging near the center of the cutter?

3. How should the wheel and work be set up for grinding a helical milling cutter?

4. How can you make up for the gradual wearing away of the grinding wheel as you grind around a cutter?

3-6. Grinding Attachments

There is a large assortment of attachments that are designed to perform some operation in conjunction with the basic machine. When these attachments are used for the jobs for which they are designed, they make grinding operations much easier. We will discuss some of the more common attachments that are used on most general purpose grinding machines.

438. State the purpose of selected grinding machine attachments.

Headstock. Although the headstock is sometimes considered a part of the basic machine, it is actually an attachment. The headstock is usually used with the universal grinding machine to provide a means of holding and driving a workpiece in relation to the cutting action of the grinding wheel.

Work Head. The work head differs from the headstock in that it normally has no provision for power. It is primarily a holding device on which a chuck, collet, or faceplate can be mounted to hold work securely for grinding operations. It is especially adaptable for the sharpening of cutters, such as gear cutters, reamers, and end mills.

Surface Grinding. You can use the surface grinding attachment for grinding flat forming tools, lathe tools, flat thread chasers, chisels, and similar work. The attachment is a vise that you can swivel in two planes. By placing the regular work head support between the vise support and the base, you can adjust the attachment in three planes. This attachment makes it possible to grind almost any flat tool without removing it from the vise. Therefore, you can maintain greater accuracy between the ground surfaces.

Gear Cutter. Since the cutters used to produce gear teeth are form cutters, they are not sharpened or ground in the conventional way. To sharpen a form cutter properly, it must be ground on the face of the tooth. The gear cutter attachment is designed to hold a cutter on an arbor in such a manner that it produces a rotary or circular motion of the cutter teeth in relation to the grinding wheel. On most cutter grinders, the grinding wheel runs in a plane perpendicular to the table. Therefore, most grinding is vertical. The gear cutter attachment provides a horizontal approach for the cutter to the grinding wheel.

Radial Grinding. As we previously mentioned, you can grind convex or concave surfaces with the aid of the radial grinding attachment. You use this attachment with the workholders to produce a convex radius on milling cutters, as shown in figure 3-26. In addition to holding work for grinding, the attachment can form the circumference of a grinding wheel into a convex or concave radius. You can do this by mounting a diamond dresser on the attachment, which then moves the diamond through the desired arc or radius and dresses and trues the grinding wheel to shape. When you are forming a wheel to a convex shape, the wheel width should be twice the desired radius. If the wheel is wider than twice the radius, a shoulder will result. If it is narrower, you cannot produce a full radius. When you are forming a wheel into a concave radius, the wheel width should be twice the desired radius plus 1/8 inch on each side to give added strength to the edges. A typical grinding operation for which you use a convex-shaped wheel is the sharpening of tap flutes.

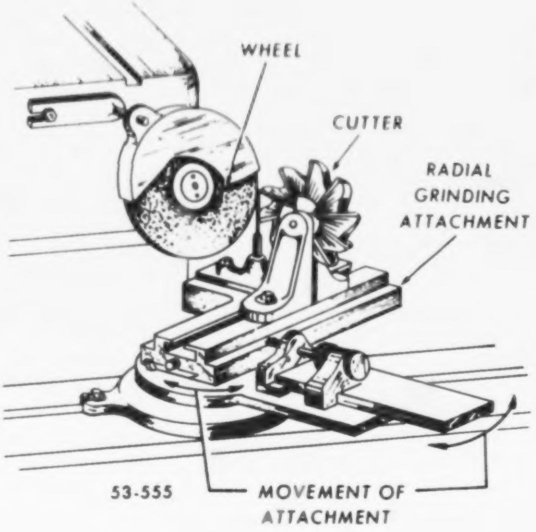


Figure 3-26. Radial grinding attachment.

Exercises (438):

1. What is the difference between the headstock and work head attachments?
2. What type of work is the surface grinding attachment used for?
3. What is the purpose of the gear cutter attachment?
4. How can the radial grinding attachment be used to form a convex or concave surface on the face of a grinding wheel?

3-7. Grinding Machine Maintenance

Maintenance is an extremely important part of your job as a machinist. It is unfortunate, but true, that many machinists do not realize the importance of proper machine maintenance. This is especially true of grinding machines. A precision machine will continue to produce precision work only as long as it is properly maintained. In this section we will discuss (1) installation, (2) preventive maintenance, (3) adjustment of gibs and spindle bearings, and (4) troubleshooting of grinding machines.

439. Cite an important grinding machine installation procedure and selected preventive maintenance measures for grinding machines.

Installation. The installation of a grinding machine does not usually require a special foundation. Any substantial floor of wood or concrete that is flat and heavy enough to support the weight of the machine is satisfactory, but you should never place a precision machine close to any machinery that has a tendency to vibrate—for example, a punch press—because outside vibration usually results in a poor finish on the work surface. The grinding machine should be leveled when it is installed in the shop. Place an accurate micrometer-type precision level on the table or in the ways in at least two directions. Also, check the level of the machine periodically because it loses its levelness through constant operation.

Preventive Maintenance. Preventive maintenance costs far less than corrective maintenance. The prevention of a costly breakdown is quite easy if you follow a few simple rules concerning cleanliness, lubrication, and corrosion control.

Cleanliness. If dirt is allowed to accumulate on a machine, it invariably finds its way into the bearings, slides, and sensitive electrical units and cause breakdown. Thorough cleaning at regular intervals will practically eliminate this hazard.

Lubrication. Proper lubrication saves time and money. Refer to the recommended lubrication schedule and follow it. When a grinding machine fails because of insufficient lubrication, it is too late to oil and grease it. The same rule applies to coolant. When coolant becomes rancid or dirty, it is time to change. Don't wait until it plugs coolant filters and damages coolant pumps. Always keep an adequate supply in the reservoir. Clean and refill the coolant tank at regular intervals regardless of machine usage.

Corrosion control. Grinding machines are especially susceptible to corrosion because most of them use water-soluble types of coolant. If water is left for a period of time on a machine surface, it will cause rust. Keep all surfaces, other than machined bearing or work surfaces, clean and painted. Not only does a clean and painted machine look better but its working life is prolonged.

Exercises (439):

1. What rule should you follow concerning other machinery when you are choosing a place to install a grinding machine?

2. Allowing dirt to build up on a grinding machine can cause what malfunction?

3. What preventive maintenance practices should you follow concerning lubrication and coolant?

440. Give the reasons for adjusting the gibs and spindle bearings.

Adjustment of Gibs and Spindle Bearings. The adjustments that can be made on the mechanical parts of a grinding machine are restricted almost entirely to the gibs and to the spindle bearings.

Gibs. The various gibs on the grinding machine should be checked and adjusted at regular intervals. The gibs are correctly adjusted when the slides move snugly by hand. If you tighten a gib too tight, the slide may become scored or galled. Loose gibs, on the other hand, cause vibration, and undue wear on the machine ways, and the machine will be inaccurate.

Spindle bearings. Spindle bearings on most grinding machines are of either the plain or the antifriction ball bearing type. Plain bearing surfaces are hardened, ground, and lapped. On some machines, bronze boxes are provided with spring shoes that automatically compensate for wear. Others are equipped with setscrews for eliminating wear and end play. Be extremely careful in making any adjustments. The bearings freeze easily if they are not adjusted correctly.

On a machine with antifriction bearings, the spindle is mounted on preloaded precision bearings. Two preloaded ball bearings take up the end thrust in both directions. The antifriction bearing has sealed lubrication and does not require adjusting or oiling.

Grinding machines with plain spindle bearings require a special, thin spindle oil because of their close tolerance. If you fail to use the recommended spindle oil in the wheelhead bearings, the shaft will eventually freeze. Too much spindle oil is harmful to the machine because the oil overflows, gets on the drive belt, and causes it to slip. If the spindle drive pulley slips, it heats and expands the spindle on its bearings. Because of the close fit, there is danger of the spindle's freezing.

Exercises (440):

1. Why must the gibs of the grinding machine be properly adjusted and readjusted regularly?

2. On a grinding machine with plain spindle bearings, what are the various ways of compensating for wear?

441. Given some common malfunctions in grinding machines, cite the possible causes.

Troubleshooting. You will be called upon many times in the course of a day's work to determine why some operation is not as satisfactory as it should be. This is especially true when you are operating a grinding machine. Grinding is a precision operation, and more things can happen to cause a malfunction in grinding than most other operations. We will cover some of the more common malfunctions and their possible causes.

Common malfunctions and causes. There are usually several possible causes for any malfunction. Overlooking one of these may result in failure to correct it. By correcting malfunctions, you can have better machine operation and produce more accurate parts. Below are some of the most common malfunctions and their possible causes:

a. Chatter can be caused by many things, such as wheel out of balance, wheel grade too hard, workcenters out of alignment, wheel not dressed properly, and dirty coolant.

b. Spiral marks on work surfaces can be caused by a misalignment of the wheel to the work, traverse feed too fast, and improper dressing.

c. Poor cutting action can be caused by the wheels being too hard, improper in-feed, gummy or dirty coolant, wheel diameter too large, or excessive spindle speed.

d. Wheels load for many reasons, such as incorrect wheel, improper dressing, dirty or improper volume of coolant, incorrect depth of cut, or excessive feed.

e. Wheel glazing is similar to wheel loading and is caused by the same conditions.

f. Work that is out of round, not parallel, or tapered is usually caused by an incorrect wheel, improperly dressed wheel, wheel incorrectly positioned in relation to work, centers or work rests improperly aligned, or work expansion caused by overheating.

g. Heat discoloration on work surfaces is usually caused by an incorrect wheel, inadequate or dirty coolant, excessive feed, or incorrect spindle speed.

h. The more common causes of wheel breaking are excessive spindle speed, improper mounting, overheating from lack of coolant, excessive wheel pressure against the work, or jamming the wheel into the work.

Exercises (441):

1. You are grinding a steel shaft and you notice spiral rings on the work. What are the possible causes?

2. If the grinding wheel does not cut properly during a grinding operation, what problems should you suspect?

3. What are the probable causes of heat discoloration on ground work?

Fitting and Assembly

FITTING AND ASSEMBLY is another important part of the machinist's job. Often, after you have manufactured the parts, you have to assemble them. Before the parts are assembled, you should carefully inspect them for accuracy and, if necessary, rework them so that they fit properly. The inspection of machined parts and the methods of assuring the proper fit and accurate assembly of machined parts are topics of discussion in this chapter.

4-1. Inspection of Machined Parts

In this section we will discuss the common methods of inspecting machined parts in the Air Force, and some of the problems that you will encounter when checking machined parts.

442. Point out special features of the common Air Force methods of inspecting machined parts.

Inspection Methods. A visual inspection of material, parts, and complete units is no longer the most important method of determining their condition. If the inspection of a part does not damage or destroy it in the process, the inspection is said to be nondestructive. Various nondestructive inspections are now used to detect variations in structure, changes in surface finish, and the presence of such physical discontinuities as cracks. Although AFSC 531X5, Nondestructive Inspection, is now a separate ladder of the metalworking career field, you should have a basic understanding of nondestructive inspection methods because there will be times when you need a nondestructive inspection of certain parts. For instance, when a part comes back to the shop after heat treatment, it should be inspected for cracks, which are sometimes too small or too well hidden to be seen easily with the naked eye.

Penetrant inspection. Penetrant inspection is used to inspect nonporous materials for defects open to the surface. A surface defect is any type of crack in connection with welding, grinding, fatigue, forging, seam laps, and poor bonding between two metals. The penetrant method is restricted to the location of defects open to the surface. The main types of penetrant inspection are dye and fluorescent:

a. Dye penetrant method. The advantages of this method are that it provides a fast, on-the-spot inspection during overhaul or shutdown periods, and its initial cost is relatively low. A perfectly white or blank surface indicates freedom from cracks and other defects that are open to the surface. Its disadvantages are that it is not practical on rough surfaces and the color contrast is limited on some surfaces.

b. Fluorescent penetrant method. The advantages of this method are that the test is positive even on rough surfaces, the procedure is easy, and the location and size of the defects are marked for visual inspection. Its disadvantages are that an ultraviolet light is needed and only clean defects open to the surface can be detected.

Magnetic particle inspection. Certain materials have the property of attracting iron and steel called magnetism. Some metals that have this property, besides iron and steel, are nickel and cobalt and some of their alloys. Magnetic particle inspection reveals surface or near-surface defects. Magnetic particles tend to adhere to the surface of a magnetized object only at points where discontinuities (such as cracks) are located. This method is not suited for very small deep-seated defects. The deeper the defect below the surface, the larger it must be to show up. With magnetic particle inspection, the surface to be inspected must be available to the inspector. This means that you cannot inspect shafts or other equipment without removing pressed wheels, pulleys, or bearing housings. This method has several advantages. It can be used on any magnetic material, and it is a positive method of finding cracks at the surface.

Eddy current inspection. Eddy current inspection is used to detect surface, or near surface, defects in most metals, to identify metals, and to detect fire damaged areas. It can be applied to airframe parts and assemblies if the defective area is accessible to contact by the eddy current probe. This type of inspection is highly sensitive.

Ultrasonic inspection. Ultrasonic inspection is used to detect surface and subsurface defects, such as cracks, lack of bond, laminations, and porosity. It can also be used for gaging thickness, detecting corrosion, and detecting air leaks in pressurized systems. One big advantage of this method is that it can be used to inspect both metallic and hard nonmetallic materials.

Radiography. Radiography includes X-ray and gamma ray inspection. X and gamma radiations, because of their unique ability to penetrate material and disclose defects, have been applied to the inspection of castings, welds, metal fabrications, and nonmetallic products. Radiographic inspection is superior to many other methods because it provides a permanent visual representation of the interior of the test objects. This method reveals the nature of a material without alteration, damage, or destruction to the material; it discloses errors in manufacturing procedures; and it discloses structural unsoundness, assembly errors, and mechanical malfunctions.

Other inspection methods. As a machinist, most of your inspection of machined parts will involve such tools as micrometers, vernier calipers and scales, and various rules and gages. We discussed the use of most of these tools in Volume 1 of this course. In addition, you will probably use certain fixed gages designed to check specific dimensions. These include the following:

a. Ring. A ring gage has a circular hole that is ground accurately to a specified size. Ring gages are frequently used in pairs, the difference in the hole sizes of the two gages equal to the tolerance of the parts being machined. A pair of ring gages is known as *go-no-go* gages. If a part fits into the larger gage but does not fit into the smaller gage, it is within tolerance. A part that fits into the smaller gage is too small and is not acceptable. A part that does not enter the larger ring gage is too large and must be remachined.

b. Receiving. Receiving gages are similar to ring gages. They are used to check the size and contour of noncircular parts. They are used quite extensively to check splined shafts.

c. Plug. The outside gaging surface of a plug gage is shaped to fit a hole. It can be round, tapered, or irregular in shape. It can have either an integral or a replaceable handle. Like ring gages, plug gages may be used in pairs as go-no-go gages.

d. Pin. Pin gages are used for measuring large holes when a plug gage is too heavy. You place the pin gage lengthwise across the hole and make the measurement as if you were measuring with an inside micrometer. Pin gages may also be used to measure the width of slots and grooves.

e. Snap. Snap gages have inside measuring surfaces for checking diameters, lengths, thicknesses, and other similar dimensions.

f. Length. A length gage is a special device designed to replace a machinist's rule. Use this type of gage when you are making a large number of parts, since the workpieces can be checked quickly.

g. Flushpin. Flushpin gages are used for gaging special shapes that may be difficult to check by conventional methods. Their primary use is to gage the depth of slots.

Exercises (442):

1. What is meant by nondestructive inspection?

2. Of the inspection penetrants, which one is most suitable for inspecting a rough forged metal part?

3. Explain how the magnetic particle inspection method works.

4. Which type of inspection is well suited for revealing material defects that are hidden below the surface?

5. What type of gage is designed primarily to check small to medium holes for shape and diameter?

6. If you had to check the depth of a large number of slots in which the surrounding irregular surfaces made conventional methods difficult, what type of gage could be made and used effectively?

443. Analyze some of the measuring problems in checking machined parts.

Checking Machined Parts. A machinist is often required to machine a replacement part. Suppose you have the task of machining a gear to replace one that has been damaged. You could measure the damaged gear and make a duplicate, but it would be much more satisfactory to obtain a blueprint and work from that. Because of wear, the dimensions of the damaged gear may not be correct. It is impossible to machine a part to mathematically exact dimensions. Furthermore, it is impossible to manufacture a measuring device that is entirely free of error. It is also impossible for a machinist, even with the aid of a magnifying glass, to read a measuring device with absolute accuracy. These observations are not intended to discourage you. We call them to your attention only to remind you that difficulties do exist and that checking is required to make sure that machined parts are within tolerance. The tolerances permitted in most machining operations in an Air Force machine shop are not so precise that they pose a serious problem to a skilled machinist. We should review some of the minute, inherent errors in checking the accuracy of a machined part. A knowledge of these errors will help you to machine parts with greater accuracy.

Instrument error. Every measuring instrument has an inherent "error of indication." The accuracy of a micrometer depends mainly upon the amount of error in the lead of the spindle thread. A new micrometer of good quality is accurate within 0.0002 inch in the range of spindle travel. The accuracy of a dial gage depends mainly upon errors of graduation and of eccentricity and friction in the transmission gearing.

As a machinist, you cannot do anything about inherent error of indication. You can, however, insist that the people in your shop treat measuring tools with the respect they deserve. Do not tolerate any abuse in the handling and use of measuring tools. The work of a highly skilled machinist is wasted if he is forced to use an inaccurate measuring tool. Keep records of the dates on the PME (precision measurement equipment) schedule, with each item of equipment listed for delivery to the PME shop for inspection and calibration. Make certain that new measuring tools are sent to the PME shop to be checked before you use them in the shop.

Error in use of tools. Obtaining an extremely accurate measurement with a micrometer is an art. When a machinist "mikes" the outside diameter of a shaft, there is no precision-indicating gage to tell him when he has turned the micrometer thimble just the right amount. Proficiency in the use of measuring tools can be developed only through on-the-job training.

Reading error. Reading error is often caused by lack of skill. For example, the trainee's first attempt to take a reading on a vernier scale can be quite confusing. Reading error from lack of skill can be reduced by additional training. Technically, "reading error" is the uncertainty of the human eye in perceiving fractional intervals on a scale. One machinist has no difficulty in determining which division marks line up on a vernier sacle; another, even with the aid of a magnifying glass, cannot determine which marks line up. There is no remedy for deficient perception, though poor eyesight can be corrected.

Exercises (443):

1. What makes even a brand-new, high-quality micrometer a source of possible error?

2. What can you do to assure that inherent instrument errors do not become magnified?

3. Why is it easy to make an error with a micrometer even if it is absolutely accurate and you are able to read the graduations perfectly?

4. What is the technical meaning of "reading error"?

4-2. Fitting and Assembly of Machined Parts

In this section, we will examine the classifications of fits and the reworking of machined parts, including homing and lapping, to assure a proper fit.

444. Explain selected types of machine fits on the basis of their effect on the assemblying of machined parts.

Machine Fits. The fitting of machined parts requires a knowledge of the types of fits and the reworking of parts. You must consider many factors in selecting a fit, because one particular application may not be effective in all situations. Some of these factors include bearing load, temperature, lubrication, materials used, and speed of moving parts. At times, the length of engagement between the workpieces must also be considered.

Types of fits. You will use various types of fits for mating parts. The type of fit to select depends upon the intended use of the parts. The following information pertains to some of the common fits and their uses. Refer to figure 4-1 for the allowances that are recommended for the various fits:

a. Standard. The standard fit is a general-purpose fit. Use a standard fit when parts must be assembled easily and when a special-purpose fit is not required.

b. Revolving or running. Use a revolving or running fit when an internal part revolves within an external part or when an external part revolves around a stationary internal part. The internal part is always smaller in diameter than the external part.

c. Sliding. Use a sliding fit when a part slides within another part. The tailstock spindle of a lathe is an example.

d. Drive. Use a drive fit to secure bushings in sleeves, pulleys, etc., and to assemble parts when other holding methods are impractical. The internal part is slightly larger than the hole in which it fits. The mating parts can be assembled with light hammer blows or with the aid of a vise.

e. Force. A force fit is like a drive fit except that the difference between the mating parts is greater. Use an arbor press or other mechanical device to assemble the parts.

f. Shrink. Use a shrink fit to obtain the maximum grip between two parts, such as a flywheel and the ring gear that fits around it. The opening in the outer part is smaller than the part it fits. Heat the outer part, causing it to expand, and then place it on the inner part. When the outer part cools, it will shrink and grip the inner part tightly.

g. Expanding. Use an expanding fit when you need a shrink fit but because of the nature of the work you cannot heat the outer member. Shrink the inner part by cooling it with solidified carbon dioxide (dry ice) or liquid nitrogen. Then place the cooled part, such as a valve seat, in the mating part and allow it to return to its normal temperature. As it warms up it will expand and tighten against the mating part.

RUNNING FITS

Diameter, Inches	For Shafts with Speeds Under 600 R.P.M. Ordinary Working Conditions Allowances, Inches	For Shafts with Speeds Over 600 R.P.M. Heavy Pressure—Severe Working Conditions Allowances, Inches
Up to ½	−0.0005 to −0.001	−0.0005 to −0.001
½ to 1	−0.00075 to −0.0015	−0.001 to −0.002
1 to 2	−0.0015 to −0.0025	−0.002 to −0.003
2 to 3½	−0.002 to −0.003	−0.003 to −0.004
3½ to 6	−0.0025 to −0.004	−0.004 to −0.005

STANDARD FITS

Diameter, Inches	For Light Service where Part is Keyed to Shaft and Clamped Endwise—No Fitting Allowances, Inches	With Play Eliminated—Part Should Assemble Readily—Some Fitting and Selecting May be Required Allowances, Inches
Up to ½	Standard to −0.00025	Standard to +0.00025
½ to 3½	Standard to −0.0005	Standard to +0.0005
3½ to 6	Standard to −0.00075	Standard to +0.00075

SLIDING FITS

Diameter, Inches	For Shafts with Gears, Clutches or Similar Parts which Must be Free to Slide Allowances, Inches
Up to ½	−0.0005 to −0.001
½ to 1	−0.00075 to −0.0015
1 to 2	−0.0015 to −0.0025
2 to 3½	−0.002 to −0.003
3½ to 6	−0.0025 to −0.004

DRIVING FITS

Diameter, Inches	For Permanent Assembly of Parts so Located that Driving Cannot be Done Readily Allowances, Inches	For Permanent Assembly and Severe Duty and where there is Ample Room for Driving Allowances, Inches
Up to ½	Standard to +0.00025	+0.0005 to +0.001
½ to 1	+0.00025 to +0.0005	+0.0005 to +0.001
1 to 2	+0.0005 to +0.00075	+0.0005 to +0.001
2 to 3½	+0.0005 to +0.001	+0.00075 to +0.00125
3½ to 6	+0.0005 to +0.001	+0.001 to +0.0015

FORCED FITS

Diameter, Inches	For Permanent Assembly and very Severe Service—Hydraulic Press Used for Larger Parts Allowances, Inches
Up to ½	+0.00075 to +0.001
½ to 1	+0.001 to +0.002
1 to 2	+0.002 to +0.003
2 to 3½	+0.003 to +0.004
3½ to 6	+0.004 to +0.005

53-556

Figure 4-1. Allowance for various fits.

Exercises (444):

1. On a 2½ inch lathe tailstock spindle, what type of fit and what allowance is required?

2. Explain the difference between an expanding fit and a shrink fit.

3. You must mount a ring gear around a metal disc, but the outer diameter of the disc is larger than the internal diameter of the gear. What type of fit should you use considering the fact that the material in the ring gear is adversely affected by high temperatures?

445. Give the reasons for reworking machined parts and key procedures in honing.

Reworking Machined Parts. Even though you took pains to machine a part to the required tolerance and specifications, you find that it just doesn't fit. Don't be discouraged. This happens to the best of machinists. At times like these, a part needs to be reworked. For example, some little imperfection in the metal, such as a high spot in the bore of a cylinder, makes honing necessary.

Reworking for final fitting and assembly often involves bench work operations. If you find that a part binds because of insufficient clearance, you can work the part to fit by handwork, filing, scraping, or polishing. Hardened parts require hand-grinding or the use of abrasive cloths and polishing and lapping compounds. If you have to remove large amounts of material, you may find it necessary to remachine the part. On occasion, you will find it more practical to remake the part. You should make a preliminary check fit of all parts before heat treatment if possible. Hardened parts are more difficult to rework.

Honing. In honing, the cutting is done by abrasive action. The abrasive particles are held by a bond in a stick or stone. (We will confine our discussion primarily to cylindrical honing.) You may do cylindrical honing on a honing machine or on some other machine tool by attaching the honing device to the machine spindle, or you may do it by hand. Regardless of the method you use, either the hone or the work must rotate and the honing tool must move back and forth with reference to the axis of rotation. For example, suppose you are using a drill press spindle to rotate the honing tool in the bore of a workpiece held in a fixture. You move the honing tool up and down in the bore with the drill press handle. If the workpiece is small enough, you can hold it in your hands and move it up and down over the rotating honing tool, but this is not advisable because of the danger of your getting caught in the rotating drill press spindle.

In honing, you can use any machine tool with a rotating spindle. For instance, on a lathe you can mount the work in a chuck and rotate it with the headstock spindle, and you can fasten the honing tool to the tailstock and move the tailstock back and forth by hand. On a milling machine or a grinding machine, you can rotate the honing tool with the spindle and move the work back and forth with the table. Most Air Force machine shops do not have enough honing work to justify the cost of a honing machine. By exercising your imagination, you can use one of the common machine tools in your shop for honing operations.

An abrasive stick is made of grit, a bond, and air voids. The grit is the cutting edge of the tool. It must be tough enough to withstand the pressure needed to make it penetrate the surface but not so tough that it cannot fracture and sharpen itself. The bond must be strong enough to hold the grit but not so strong that it rubs on the bore and interferes with the cutting action of the grit. Air voids in the structure of the stick aid the coolant in clearing chips and in dissipating heat. The coolant flushes the abrasive from the surface of the metal. If chips or sludge collect on the sticks, they will glaze over and act hard. The coolant dissipates the heat generated by shear and friction. Even a small rise in the temperature of the part can affect the size and roundness of the bore. The most satisfactory coolant is one with a sulphurized mineral base of lard oil mixed with kerosene. Water-soluble oils have not proved satisfactory.

You can hone any ferrous and nonferrous metal. Hardness is not a limiting factor, but it effects the rate of stock removal. For soft metals, the rate may be as high as 0.025 ipm (inch per minute) from the diameter. For hard steel, the rate may be from 0.006 ipm to 0.012 ipm from the diameter when the length of the part is three or four diameters. The bore that you are honing may be interrupted by ports, keyways, and undercuts. If there is enough area to stabilize the action of the abrasive stick, you can hone the bore.

Honing may be used to remove stock and correct taper, out-of-roundness, or bow. Also, it may be used to develop the desired finish and to accurately control size. Honing does not change the axial location of a hole. The centerline of the honing tool aligns with the centerline of the bore. Either the tool or the part floats to insure that the tool and the bore align. Float enables the tool to exert equal pressure on all sides of the bore. The abrasive sticks, which are inserted in the circular honing tool (much like inserted milling cutter teeth), expand radially by the wedging action of a cone (or some other device). As a honing tool is stroked through the bore, the pressure of the grits (penetration) is greatest at the tight spots. Thus, all taper and out of roundness are taken out before any stock is removed from the larger section of the bore. Also, any bow in the bore is taken out. Since the abrasive sticks are rigid throughout their full length, they cannot follow a bow—they bridge the low spots and cut deeper on the high spots, tending to straighten out a bow.

After you have honed out the inaccuracies, you must abrade every section of the bore equally. To insure that this happens, the rotating and reciprocating motions must be at an odd ratio to each other. Thus, every part of the bore is covered before any grit repeats its path of travel.

If a bore requires honing to correct taper or out of roundness, about twice as much stock should be left for honing as there is error in the bore. It is sometimes practical and economical to perform two honing operations: (1) rough honing to remove stock and (2) finish honing to develop the desired finish. From 0.0002 to 0.001 inch of stock should be left on the diameter for finish honing. If a machined bore must be heat treated, rough hone it before heat treating to produce an accurately sized, round, and straight bore. After heat treating, finish hone the bore to correct any minor distortion and to produce the desired finish.

Honing produces a crosshatch finish. The depth of cut depends upon the abrasive, speed, pressure, and coolant. To produce a finer finish, you can do one or all of the following:

- Use a finer grit.
- Increase the rotation speed.
- Decrease the reciprocation speed.
- Decrease the pressure.
- Increase the viscosity of the coolant.

Exercises (445):

1. Why is reworking newly machined parts sometimes necessary?

2. List the alternatives when you are choosing a method for reworking a machined part.

3. Explain the principle of operation of honing.

4. What is the preferred method of honing work in a drill press?

5. Give the various uses of the honing operation.

6. How does a hone effectively remove low or high spots without making every surface of the bore larger?

7. How much stock should be left for finish honing?

446. State the purpose of the lapping process and compare various lapping procedures.

Lapping. Lapping is another method of reworking machined parts. It is similar to honing because it cuts by abrasive action. However, in lapping, the abrasive particles are loose between the lap and the work.

Several years ago, manufacturers recommended a "breaking in" period for new car engines. The owner was advised to drive under 50 mph for the first 500 miles, and he was told that the oil consumption would be greater during the breaking in period. In recent years, a breaking in period has not been recommended. Why? The reason is the improvement in lapping cylinders and piston rings. Piston and cylinder surfaces fit together better, and it is not necessary to wear the high spots away. A fine film of oil quickly forms between mating surfaces, resulting in more efficient lubrication and less oil consumption.

You can lap work by hand or by machine. Unless your shop does production work, you are more likely to do hand lapping, which includes flat, hole, and ring (external) cylindrical lapping.

You lap work to improve the surface finish and to remove surface waves, roughness, toolmarks, slight distortions, and defects left from a preceding operation. Several features are associated with lapping:

a. Loose abrasives are used between the lap and the work.

b. The lap and the work are not positively driven but are guided in contract with each other.

c. Fresh points of contact are made between the lap and the work by constantly changed relative movements.

d. The lap is softer than the work and acts as a holder for the abrasive.

e. The abrasive is harder than the work.

f. Plain-faced laps are preferred for fine flat lapping and all cylindrical lapping.

g. Serrated laps are preferred for flat work with large areas and for faster stock removal.

Lapping increases wear life by removing surface roughness and geometrical irregularities that would otherwise have to be removed by "running in." Lapping produces a very fine finish. Liquid and gas-tight seals can be obtained without the use of gaskets and, between plunger and cylinder, without the aid of piston rings. Lapping also provides an accurate plane from which other planes on the same workpiece may be accurately located.

The abrasive particles are mixed with a carrier vehicle, such as oil, grease, or a soap and water compound. The vehicle suspends the abrasive particles and keeps them separated, lubricates the work, and prevents scoring. Abrasives are classified as hard, hard and sharp, and varying grades of softness. Hard and sharp abrasives do not break down in use and must be accurately classified in order to cut fast and give a good finish. In general, you should select hard abrasives to lap hard work and soft abrasives to lap soft work. The diamond is the hardest of all abrasives, and is very useful in lapping tungsten carbides. The finest grit sizes, although expensive, can be used with excellent results to lap hardened steel. Next in hardness are the manufactured abrasives, silicon carbide and aluminum oxide. If you use the proper grit sizes, these abrasives are efficient and economical and you can use them for nearly every type of lapping. Manufactured abrasives are available in all grain sizes from coarse to superfine flours.

A thin, oily abrasive is best for lapping hardened steel. A smooth paste or grease-type abrasive is best for lapping soft metals. The quality of the finish is controlled by the vehicle, as well as by the abrasive. A poor vehicle will scratch and prevent proper cleaning. Do not mix abrasive grit sizes. The laps should be dressed with the same abrasive that is used to lap the work.

The tools for hand lapping are quite simple. For lapping flat work, you should use a lapping plate on which you rub the work by hand. You may charge the plate by sprinkling dry abrasive on the face of the plate and wetting it with oil, or by brushing on an abrasive compound. Apply the abrasive sparingly; too much abrasive increases the wear on the lap without doing any additional work. Rub the work on the plate with a "figure-eight" motion to obtain a uniform abrasive action. A circular lapping plate is preferred to a rectangular plate because it is easier to dress and keep flat. The surface may be serrated or plain faced. V-shaped grooves are easier to clean than plain saw cuts. Saw cuts leave sharp edges that are difficult to wipe clean.

You can also lap external cylindrical work. This type of lapping is commonly called ring lapping. Ring laps are usually made of soft, close-grain cast iron. The simplest type of ring lap is a bushing split on one side. You can hold this lap in a lathe dog and use the binder screw to close the lap around the work. A better type of lap has one or more partial cuts, in addition to the complete slit. It also has adjusting screws to close or expand the lap. The bore of the lap must be smooth, straight, and close to the size of the work.

The length of the lap should be slightly shorter than the length of the work. On long spindles, the length should not exceed three or four diameters; a greater length is difficult to handle. Adjust the lap so that the work will warm up slightly. When the lap is reciprocated, it should overrun the work about one-third the length of the lap. Permit the work to cool before measuring it.

Select the abrasive and the vehicle that are suited to the material being lapped because scratches once made are difficult to remove. It is best to begin with fine abrasive compounds that cut fast, since they become still finer with use and thus produce a good finish. Feed the abrasive compound through the slot to maintain a straight, round hole in the lap.

Ring lapping is recommended for lapping stepped-plug gages, gages made in small quantities, and precision machine spindles in which accurate roundness is essential. Considerable skill is required to do quality work. Not more than 0.0005 inch of stock should be removed. Hardened steel is easiest to lap and receives the highest finish. You should use a specially selected abrasive for soft steels; otherwise, the work will score.

Exercises (446):

1. What takes place when a part is lapped?

2. What is the purpose of the lapping process?

3. What type of lap is most commonly used for cylindrical work?

4. Explain the action of the "vehicle" in a lapping compound, and list the various types of vehicles?

5. Describe the simplest form of the type of lap used on external cylindrical work.

6. When you are lapping external cylindrical work with a ring lap, how should the abrasive compound be fed into the lap?

Bibliography

Books

Oberg, Erik, and Franklin D. Jones. *Machinery's Handbook,* Nineteenth Edition. New York: Industrial Press, 1974.

Colvin, Charles H., Henry F. Colvin, and Eleanor Stanley, *The New American Machinist's Handbook*. New York; McGraw Hill Book Company, 1973.

Walter, John R. *Modern Metalworking.* Illinois: The Goodheart-Wilcox Company, Inc., 1973.

Department of the Air Force Publications

AFR 127-101, *Accident Prevention Handbook.*

TO 34-1-3, *Inspection and Maintenance of Machinery and Shop Equipment.*

TO 34-1-10, *Fundamentals of Ordnance Corps Machine Tools.*

NOTE: None of the items listed in the bibliography above are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell ASB AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only *books* and a limited number of *AFMs*. TOs, classified publications, and other types of publications are *not* available. Refer to current indexes for the latest revisions of and changes to the official publication listed in the bibliography.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 - 1. 1. c.
2. d.
3. b.
4. g, i.
5. a, e.
6. f.
7. h.
8. k.
9. j.

401 - 1. Side milling cutters are plain cutters with teeth on the side as well as on the circumference. They are used to machine the sides of a part accurately, as in straddle milling.

401 - 2. The type, hand, outside diameter, thickness, hole size, and angle.

401 - 3. The cutters over 1 1/2 inch in diameter usually must be mounted on an arbor while those under 1 1/2 inch have a shank.

401 - 4. Number 50.

401 - 5.
4 = number 40 milling machine taper (1 3/4 inch, large diameter)
1 = a 1-inch shaft diameter.
A = style A arbor (pilot)
12 = a 12-inch usable shaft length

401 - 6. 42M—a number 40 milling machine taper outside with a number 2 Morse taper inside; 58—a number 50 milling machine taper outside and a number 8 Brown and Sharpe taper inside.

401 - 7. Cutter adapters have a milling machine taper outside and straight holes on the inside. They are used to hold straight shanked tools, such as end mills and small Woodruff keyseat cutters.

402 - 1. Determine the difference in rpm from the spindle to the cutter and then add that difference to or subtract it from your rpm calculations to assure the *cutter* will turn at the required rpm.

402 - 2. $\text{rpm} = \dfrac{4 \times 75}{6}$

$\text{rpm} = 50$

402 - 3. Make sure that the gibs are snug and that excessive backlash has been removed from the lead screw. Also, tighten the table lock until you feel a slight drag. Climb milling tends to pull the work into the cutter, which could damage both the work and the cutter.

402 - 4. From 0.001 inch to 0.015 inch.

402 - 5. $\text{Thickness} = \dfrac{1.50}{15 \times 50}$

$\text{Thickness} = .002$

402 - 6. $\text{Feed} = 0.006 \times 16 \times 60$

$\text{Feed} = 5.76$ inches per minute.

402 - 7. They should be decreased.

403 - 1. To mill a flat surface in a plane parallel to the cutter's axis.

403 - 2. As near as possible to the column. To allow the cutter to be mounted near the column on the arbor for rigidity.

403 - 3. To mill surfaces perpendicular to the cutter's axis.

403 - 4. The cutter's diameter should be larger than the thickness of the work.

403 - 5. It should be positioned so that the thrust of the cutter is down and toward the solid jaw.

404 - 1. To cut several different surfaces on a workpiece at the same time by using two or more cutters.

404 - 2. The spacing and width of the cutters to be used.

404 - 3. Straddle milling is mounting two cutters at a specified distance apart on an arbor [illegible] purpose of milling two opposite sides of a workpiece at the same time.

404 - 4. Use the toolmaker's knee to position the work at the required angle to the cutter; use angular parallels to support the work at an angle to the cutter.

405 - 1. To bore holes accurately on a milling machine.

405 - 2. The boring head is equipped with a graduated collar for moving the tool bit along the diameter of the head.

405 - 3. Form cutting (gear teeth, splines, etc.), boring, plain or face milling, and angular milling.

405 - 4. Lathe-type tool bits.

406 - 1. For internal machining of such things as splines, gears, sockets, keyseats, and tool and die work.

406 - 2. It is mounted to the column; the rotating motion of the spindle is changed to a reciprocating motion in the slotting attachment.

406 - 3. By setting the spindle rpm.

406 - 4. 160 strokes per minute.

406 - 5. It provides better vision of the cutting action

407 - 1. 6 flutes.

407 - 2. 1 inch; 1/2 inch.

407 - 3. A formed fluting cutter.

407 - 4. 3/4 inch to 1 inch reamers; 8 flutes.

407 - 5. 2°.

407 - 6. A fly cutter ground to the shape of a reamer flute close to the size being machined.

408 - 1. A Woodruff cutter or a two-lipped end mill.

408 - 2. You should remove the table 1/2 the shaft diameter plus 1/2 the cutter width.

408 - 3. The depth of the keyseat and the height of the arc.

408 - 4. 0.125 inch.

408 - 5. Mount it on an arbor.

408 - 6. $\text{Reading} = \text{shaft dia} + \dfrac{\text{width of key}}{2} - \text{height of arc}$

$\text{Reading} = 1 + \dfrac{0.250}{2} - 0.0159$

$\text{Reading} = 1 + 0.125 - 0.0159$

$\text{Reading} = 1.1091$ inches

409 - 1. By hand.

409 - 2. $\frac{40}{16} = 2\frac{8}{16} = 2\frac{1}{2} = 2\frac{9}{18}$

Therefore, 2 turns and 9 holes in an 18 hole circle will produce 16 divisions.

409 - 3. The adjustable sector arms.

409 - 4. In degree indexing the spacing between the holes or surfaces represents degrees instead of divisions.

409 - 5. 60°.

409 - 6. Each turn equals 9°, therefore 9° × 19 turns = 171°.

409 - 7. $\frac{28\ 1/3}{9} \times \frac{3}{3} = \frac{85}{27} = 3\frac{4}{27}$

Therefore, 3 turns and 4 holes in a 27 hole circle will rotate the work 28 1/3°.

409 - 8. In wide range indexing, the index head has two index cranks and plates and many more divisions can be obtained than in plain indexing.

409 - 9. $400{,}000 \div 108 = 3{,}703\frac{7}{108},\ 1 \div \frac{7}{108} = 1 \times \frac{108}{7} = 15$ (nearest whole no.)

Therefore, the large index crank should be moved 37 holes and the small crank should be moved 3 holes plus 1 extra hole every 15th division.

409 - 10. In compound indexing, the crank is moved a certain number of holes in one hole circle and then the index plate is revolved a certain number of holes in the *opposite* direction using a different hole circle.

410 - 1. Use the longitudinal feed graduated dial to move the table the required spacing.

410 - 2. Gear the table to the index head and make the divisions with the index head.

410 - 3. 2 1/2 turns = 1/64 inch
5/64 inch = 5 × 2 1/2 = 12 1/1 turns.

410 - 4. Either a stationary single point tool or an angular cutter.

410 - 5. It is held and rotated in an indexing head.

411 - 1. The high-speed universal attachment and the circular milling attachment.

411 - 2. The cutter is set at 90° to the T-slots in the milling machine table.

411 - 3. The right angle plate, which allows the index head to be positioned either parallel or perpendicular to the axis of the spindle; and the raising blocks, which raise the index head to allow larger work to be rotated in the index head chuck.

411 - 4. It allows work to be held at various angles, either single or compound, by means of a tilting and swiveling table.

411 - 5. They change the rotary motion of the spindle into a reciprocating motion.

412 - 1. By causing the work to rotate at the same time that it is fed longitudinally to the cutter.

412 - 2. The lead of a helix is usually much greater than the lead of a thread.

412 - 3. 5.862 inches.

412 - 4. 0.23562.

412 - 5. Compound gearing uses two driving gears and two driven gears to produce the same ratio that would be produced if one driving gear and one driven gear could be used. It is used when the two gears that are compatible to the lead ratio are not available.

412 - 6. Factor each member of the ratio and then multiply both therms of each factor by a number that will result in a number matching the number of teeth on available gears.

412 - 7. For the drill bit, you use the outside diameter in the calculations; for the helical gear, you use the pitch diameter.

413 - 1. Miter gears are equal in diameter. In a gear and pinion set, the gear is larger than the pinion.

413 - 2. The cutting or root angle.

413 - 3. $\text{Pitch diameter} = \frac{\text{number of teeth}}{\text{diametral pitch}} = \frac{20}{5} = 4.0 \text{ inches}$

$$\text{Whole depth of tooth} = \frac{2.157}{5} = 0.4314 \text{ inch}$$

$$\text{Thickness of tooth} = \frac{1.571}{5} = 0.3142 \text{ inch}$$

413 - 4. Set the gear blank off center a specified amount and then rotate it slightly. Shave each tooth at that setting and do the same operation for the other side of the teeth. After you have obtained the correct tooth thickness throughout their length, hand file the teeth to the proper form above the pitch line.

414 - 1. A dimension plan of the machine should be studied to be certain that the selected spot is big enough to allow plenty of room around the extreme dimensions of the machine.

414 - 2. By keeping a light film of clean oil of them.

414 - 3. The slides will become scored. The machine will chatter and vibrate during machining operations.

414 - 4. The right-hand end.

414 - 5. The crossfeed hand wheel, the power feed lever, and the graduated dial.

CHAPTER 2

415 - 1. High-speed lathe tool bit blanks, 3/8 inch or larger.

415 - 2. 3° to 5° plus the angle at which it will be held in the toolholder.

415 - 3. A depth of cut of 0.005 or less and the finest feed possible.

415 - 4. To finish the bottom and sides of shoulders, keyways, grooves, etc.

415 - 5. 1/16 inch.

416 - 1. You would need to decrease the end relief and back rake angles.

416 - 2. One type has a single clamping screw and the other type has two clamping screws.

416 - 3. Take light cuts only.

416 - 4. To prevent work from shifting sideways on the table during a shaper operation.

417 - 1. The bull wheel, rocker arm, and connecting link.

417 - 2. A lead screw, which is connected to a crank shaft through bevel gears, moves a sliding block mechanism along a stationary slide on the bull wheel. A change in the position of the sliding block causes the rocker arm to move the connecting link and the ram a different distance.

417 - 3. There should be 1/8 inch overstroke at the end of the cut to allow the chip to break off and 7/8 inch at the start of the cut to permit the clapper box to seat properly before the next cut.

417 - 4. In strokes per minute.

417 - 5.

$$\text{Number of strokes per minute} = \frac{\text{CFS} \times 7}{\text{length of stroke}}$$

$$\text{Number of strokes per minute} = \frac{60 \times 7}{10 \text{ (plus 1 inch overstroke)}}$$

$$\text{Number of strokes per minute} = 42$$

417 - 6. The highest speed and longest stroke.

417 - 7. Just before each cut.

418 - 1. The work should be fed from left to right and the toolslide should be fed from top to bottom; this provides the best vision of the cutting action.

418 - 2. Parallel to the movement of the ram.

418 - 3. To allow the work to be seated on the parallels properly.

418 - 4. Side one should be positioned against the solid jaw of the vise.

419 - 1. The toolhead should be aligned square with the table or vise and the top of the clapper box should be tilted away from the surface being machined.
419 - 2. The squaring tool.
419 - 3. The side finishing tool; the 1/16 inch cutting edge should be set up parallel with the surface to be machined.
419 - 4. Vertical feed must be done by hand (the power feed is only for horizontal table movement).

420 - 1. The clapper box should be positioned centrally and the toolholder should be positioned vertically.
420 - 2. When the tool is approximately 1/8 inch from the shoulder layout line.
420 - 3. File the burrs off the top surface of the shoulder.
420 - 4. Use a side-finishing tool for the vertical surface and a squaring tool for the horizontal surface and the corner.

421 - 1. The work should never be parted with the parting groove parallel to the vise jaws.
421 - 2. As wide as the required keyseat.
421 - 3. Lay out the keyseat; drill one hole at the end of the keyseat at which the cut will terminate and two adjacent holes at the starting end of the keyseat. The holes should be equal in diameter to the keyseat width and as deep (not counting the point cone) as the required keyseat depth; remove the excess metal between the two adjacent holes.
421 - 4. Insert the key and measure over the key and the shaft with a micrometer.
421 - 5. The tool is held in an extension toolholder. The clapper box and toolholder are aligned vertically and the clapper box is locked. The tool and the work are positioned so that the cut is at the top of the hole and the tool is fed upward.

422 - 1. By swiveling the vise, swiveling the toolhead, swiveling or tilting the table, or mounting the work either on an adjustable angle plate or on a fixture.
422 - 2. With the graduations around the toolhead. Use a size bar setup and a dial test indicator.
422 - 3. The fixture, because the adjustable angle plate is suitable *only* for light duty machining.

423 - 1. Rough the contours with a roundnose tool and then use a form tool.
423 - 2. Layout the contour on the end of the work and then machine to the layout line by moving the work and the toolslide simultaneously.

424 - 1. Adequate space for ram movement and operator movement around the shaper and a solid foundation.
424 - 2. Make sure that there is adequate ventilation.
424 - 3. 0.002 inch.
424 - 4. A small amount of oil applied at regular intervals is better than a flood of oil at irregular intervals.

CHAPTER 3

425 - 1. Abrasive and bond.
425 - 2. The forces acting on the grinding wheel during its operation cause the abrasive grains to fracture and expose new cutting edges.
425 - 3. Silicon carbide is extremely hard, but tends to fracture easily; aluminum oxide is only slightly softer, but it does not fracture as easily.
425 - 4. It holds the abrasive grains in place, controls the hardness of the wheel, and provides the wheel safety factor at running speed.
425 - 5. Vitrified.
425 - 6. It releases abrasive grains quickly, an operation that tends to dissipate heat build up and prevents the burning of the cutting edges of cutters during sharpening.
425 - 7. Because they are strong and very flexible during operation.

426 - 1. 1. a.
2. j.
3. h.
4. b.
5. i.
6. g.
7. k.

427 - 1. The type of material to be ground.
427 - 2. A hardened material to be ground; a large area of contact.
427 - 3. An abrasive cutoff operation.
427 - 4. Support it on your finger or a string and tap it with a nonmetallic instrument. It will not ring, but will have a "dead" sound if it is cracked.
427 - 5. By carefully chiseling away a portion of the wheel next to the bushing on the light side and filling it with lead.

428 - 1. Approximately 1/3 of the grinding wheel.
428 - 2. Insert paper blotters between the flanges and the grinding wheel; tighten the flanges with the spindle nut just snugly enough to prevent the wheel from slipping.
428 - 3. They should be tightened in alternating sequence, first, one side, then the side opposite, etc., around the collet.
428 - 4. Dressing improves or alters the cutting action of the wheel while truing restores concentricity to the wheel face.
428 - 5. The diamond wheel dresser.
428 - 6. It prevents the diamond from gouging and chattering.
428 - 7. If the grinding is to be done with coolant, then the dressing should be done with coolant; if the grinding is to be done dry, then the dressing should be done dry.
428 - 8. You are feeding the dresser too slowly.

429 - 1. In surface feet per minute (sfpm).
429 - 2. sfpm = diameter of wheel × 0.2618 × rpm
sfpm = 10 × 0.2618 = 2,250
sfpm - 5,890.5
429 - 3. You would have to use a wheel with a larger diameter.
429 - 4. $\text{rpm} = \dfrac{\text{sfpm}}{\text{diameter of wheel} \times 0.2618}$

$\text{rpm} = \dfrac{6{,}000}{9 \times 0.2618}$

rpm = 2,546 (rounded off to nearest whole number)

429 - 5. $\text{rpm} = \dfrac{\text{sfpm}}{\text{diameter of work} \times 0.2618}$

$\text{rpm} = \dfrac{70}{2 \times 0.2618}$

rpm = 134 (rounded off to nearest whole number)

430 - 1. By moving the wheel toward the work.
430 - 2. To remove warpage, to reduce work diameter to exact size, and to improve the finish.
430 - 3. The work and the grinding wheel should rotate in opposite directions.
430 - 4. It provides a smooth, accurate bearing and mounting surface and helps prevent damage to the machine centers.
430 - 5. The cutting efficiency is reduced and the heat build up is increased.
430 - 6. Mount a piece of hardwood with a 60° point (covered with lapping compound) in a lathe or drill press.

431 - 1. The spindle shaft should be aligned parallel to the table.
431 - 2. It should be held between centers and driven with a drive dog.
431 - 3. In fractions of wheel width per work revolution.
431 - 4. Table traverse = (width of wheel × fraction × work rpm) ÷ 12
Table traverse = (1.5 × 1/6 × 100) ÷ 12

Table traverse = $25 \div 12$
Table traverse = 2.08 or approximately 2 1/6 fpm.

431 - 5. Table movement = (TPI × distance between swivel point and indicator) ÷ 2
Table movement = $(0.0025 \times 15) \div 2$
Table movement = $0.0375 \div 2$
Table movement = 0.01875 inch movement at the dial indicator.

431 - 6. During flute grinding the reamer should rotate in the same direction as the wheel at the point of contact to obtain clearance behind the reamer teeth.

432 - 1. The shank and point of a lathe center and taper plug gages.

432 - 2. The axis of the work should be aligned at an angle with the line of motion of the table.

432 - 3. The wheel axis is probably above or below the axis of the work.

432 - 4. By swiveling the workhead.

432 - 5. Improving finishes on bored and reamed holes, and the exact sizing of holes of various diameters.

432 - 6. The internal grinding attachment.

432 - 7. Since the spindle rpm must be much greater, the wheel will load quickly, causing vibration and poor surface finish.

432 - 8. Because the spring in the quill will produce a bell-mouthed hole.

433 - 1. The angular wheel method; the straight wheel method; and the cup wheel method.

433 - 2. Because it usually involves the smallest area of contact.

433 - 3. Because the side of the cup wheel would have to be used, which is not an accepted practice.

433 - 4. Both the side and face of the straight wheel are used. The side of the wheel should be recessed to reduce the area of contact. Both the cylindrical surface and the shoulder face should be ground together.

433 - 5. Feed the wheel straight in to the recess with no table traverse (called plunge grinding). Use a hard grade, straight sided or recessed sided wheel.

433 - 6. The desired form should be cut into the wheel face. Use that wheel to grind the form onto the work, using extremely light cuts to prevent burning the work.

434 - 1. On the reciprocating table type, the work is mounted on the table, which passes the work back and forth under the face of the wheel, which is fed into the work; on the rotating table type, the work is rotated on a circular table, which passes under the wheel face, which moves back and forth along the table radius. The work is fed into the wheel.

434 - 2. Mount the diamond dresser at an angle toward the wheel rotation. Position the wheel directly above the diamond. Start the wheel rotation, feeding it carefully until it touches the diamond, and then turn on the coolant. Dress the wheel by moving the table back and forth with the crossfeed handcrank.

434 - 3. They should be positioned so that the wheel will run off the ends of the parallel.

434 - 4. Pick up the cut while the table is in motion. As soon as contact is made, turn on the coolant.

434 - 5. No more than 0.002 for roughing and no more than 0.0005 for finishing.

435 - 1. To remove warpage and nicks, to obtain a specific diameter, and to produce a fine finish and a slight cutting edge clearance.

435 - 2. In theory, it produces a slight clearance on the back of the cutting edges that cannot be obtained if they are ground in the normal direction for cylindrical grinding.

435 - 3. You must be careful to keep the cutter from slipping away from the toothrest because of the force of the cutting action.

436 - 1. The primary clearance provides for a smooth cutting action and reduces friction. The secondary clearance provides strength to the tooth and controls the width of land.

436 - 2. 5° to 7° angle and 1/32 inch width of land.

436 - 3. The type of wheel used, the shape of the work, and the location of the toothrest.

436 - 4. 0.264 inch.

437 - 1. On the tooth face only.

437 - 2. The end teeth should be tapered toward the middle of the cutter approximately 1/2° to 1°.

437 - 3. The cup wheel should be swiveled slightly so that only one side contacts the cutter. The cutter can be held on a mandrel, arbor, or between the left- and right-hand footstock and the toothrest should be positioned under the cutter tooth at the proper height.

437 - 4. By grinding all the way around the cutter twice but starting the second time around 180° from the first starting point.

438 - 1. The headstock is power driven while the work head has no provision for power.

438 - 2. For grinding such tools as flat forming tools, lathe tools, chisels, etc.

438 - 3. Its primary use is in sharpening the teeth or gear cutters.

438 - 4. By mounting a diamond dresser on the attachment which can then be used to move the dresser through the desired arc or radius.

439 - 1. The grinding machine should not be located near a machine that vibrates.

439 - 2. It will get into the bearings, slides, and electrical parts and damage them.

439 - 3. The machine should be lubricated regularly before it fails from the lack of lubrication. The coolant should be changed as soon as it becomes rancid or dirty to prevent damage to the coolant pumps.

440 - 1. Because if they get too loose, they cause vibration, wear on the ways, and inaccurate work; if they are too tight, they can cause scoring or galling of the ways.

440 - 2. Some machines are equipped with spring-loaded shoes in the spindle bearing area which automatically compensate for wear. Other types of machines have set screws for eliminating spindle bearing end play and wear.

441 - 1. The misalignment of the wheel to the work, the wheel not dressed properly, or travel feed too fast.

441 - 2. The wheel is too hard, the coolant is gummy, the wheel diameter is too large, or the wheel speed or feed is excessive.

441 - 3. A wrong choice of wheel, dirty coolant, too much feed, or improper wheel speed.

CHAPTER 4

442 - 1. Any inspection method that does not damage or destroy the part being inspected.

442 - 2. Fluorescent penetrant.

442 - 3. It works on the theory that magnetic particles will adhere to a magnetized part in heaviest concentration around defects in the material.

442 - 4. Radiography.

442 - 5. Plug gage.

442 - 6. Flushpin gage.

443 - 1. There is a certain amount of error in the lead screw and in other machined surfaces in the micrometer than can add up to 0.0002 inch or more error in the length of travel.

443 - 2. Take special care of your measuring devices. Make sure that they are not mistreated and that they are regularly inspected and calibrated.

443 - 3. Because of the fact that there is no positive means of

knowing exactly when you have turned the thimble at just the right amount.

443 - 4. It is the uncertainty of the human eye in perceiving fractional intervals on a scale.

444 - 1. A sliding fit with 0.002 to 0.003 inch allowance.

444 - 2. For an expanding fit, an internal part must be cooled (shrunk) to fit into an external part; for a shrink fit, an external part must be heated (expanded) to fit around an internal part.

444 - 3. Use an expanding fit.

445 - 1. Because little imperfections that get overlooked during machining prevent parts from fitting or assembling properly.

445 - 2. Honing, filing, scraping, polishing, grinding, sanding, and even remachining or remaking the part.

445 - 3. Honing is using a stick or stone made of a bond and abrasive particles which act as tiny cutters on the part being honed.

445 - 4. Hold the work in a fixture, mount the hone in the spindle, and move it up and down in the work.

445 - 5. To correct taper and out of roundness, to remove stock, to develop a desired finish, and to accurately control size.

445 - 6. The hone is not flexible and, therefore, cannot follow a contour. It will, instead, act to straighten a contour by cutting the high spots down to the level of the low spots.

445 - 7. From 0.0002 to 0.001 inch of stock.

446 - 1. Abrasive particles, which are loose between the work and lap, cut the work while either the work or the lap is moved over the other.

446 - 2. To improve the surface finish, to remove surface waves, and to remove other slight distortions on the work surface.

446 - 3. Plain-faced lap.

446 - 4. The vehicle suspends the abrasive particles and keeps them separated and lubricated to prevent scoring the work. Oil, grease, or water-soap solution.

446 - 5. A bushing that is split on one side and held in something capable of closing the lap around the work, such as a lathe dog.

446 - 6. Through the full length split in the side of the lap.

STOP -

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 2 PENCIL ONLY.

53150 03 24

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

ADVANCED MACHINE WORK

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DONT'S:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

1. (400) The knee on a milling machine is fastened to the column by

   a. saddle tail ways.
   b. dovetail ways.
   c. a table feed slide.
   d. milling bolts.

2. (401) A type of a milling cutter that is used to cut off work or to mill narrow slots is the

   a. double-edged side milling cutter.
   b. single-edged side milling cutter.
   c. metal slitting saw.
   d. angle cutter.

3. (401) In the milling machine arbor number 4-1-B-12-3, the letter "B" means that the arbor has

   a. a Brown and Sharpe taper.
   b. a pilot-type bearing and not a sleeve-type.
   c. both a sleeve and a pilot-type bearing.
   d. a sleeve-type bearing and not a pilot-type.

4. (401) The number 54M on a milling machine taper adapter means that the adapter has a number

   a. 50 milling machine taper outside and a number 4 Morse internal taper.
   b. 5 Morse taper outside and a number 4 Morse internal taper.
   c. 54 Morse internal taper.
   d. 50 milling machine taper outside and a number 40 milling machine taper inside.

5. (402) If you are using a milling machine attachment in which the rpm ratio between the spindle and the cutter is 2 to 1, and you have determined that a cutter speed of 100 rpm is required, at what rpm should the machine be set?

   a. 50 rpm.
   b. 100 rpm.
   c. 200 rpm.
   d. 250 rpm.

6. (402) What feed would be required to obtain a .005 inch chip thickness while milling a job with a speed of 80 rpm and a cutter containing 20 teeth?

   a. 0.004 inch per revolution.
   b. 0.008 inch per revolution.
   c. 4 inches per minute.
   d. 8 inches per minute.

7. (403) The process of milling a flat surface in a plane parallel to the cutter's axis is an example of

   a. plain milling.
   b. face milling.
   c. angular milling.
   d. vertical milling.

8. (404) A setup in which two square sides can be machined at the end of a rod or shaft with one pass is called

   a. angular milling.
   b. straddle milling.
   c. square milling.
   d. end milling.

9. (405) You must mill teeth on a badly needed replacement gear for which you have no available gear tooth milling cutter, but you have a portion of the old gear as a sample. You should then

a. grind a tool bit to the required form and fly cut the teeth.
b. try to determine the tooth size and order the correct cutter.
c. grind a larger size gear cutter down to the required size.
d. use the closest size gear cutter available and hand file the teeth to the required form.

7

10. (406) When setting up a job on a milling machine with the slotting attachment, the work should be held

a. horizontally for cutting squares or hexagons.
b. vertically whenever possible.
c. vertically for cutting splines only.
d. horizontally whenever possible.

11. (407) If you mill tap flutes on a 1 1/2-inch tap blank, how many flutes would you usually cut?

a. 2.
b. 3.
c. 4.
d. 6.

12. (407) When you mill flutes on a straight fluting reamer, you should be sure that the reamer teeth are cut with a

a. slight positive rake and with a recommended 4° variation in spacing.
b. slight negative rake and with no variation in spacing.
c. 0° rake and with a recommended 2° variation in spacing.
d. slight negative rake and with a recommended variation in spacing of 2°.

13. (408) To mill a 1-inch-long straight external keyseat 6 inches from the end of a 20-inch-long shaft, which of the following cutters would not normally be used?

a. A plain milling cutter.
b. A two-lipped end mill.
c. A four-lipped end mill.
d. A Woodruff cutter.

14. (408) What two dimensions must you add together to obtain the total depth of cut to mill a Woodruff keyseat?

a. The depth of the keyseat plus the height of the arc.
b. The depth of the keyseat plus 1/8 times the shaft diameter.
c. The height of the arc plus the arc plus the shaft diameter divided by 4.
d. The height of the arc plus 2 times the width of the key.

15. (409) If you use a plain indexing head with a 40 to 1 ratio and a 36-hole circle on the index plate, how many turns and holes are required to obtain 1[illegible] divisions?

a. 2 turns and 0 holes.
b. 2 turns and 4 holes.
c. 0 turns and 18 holes.
d. 2 turns and 8 holes.

16. (410) The most accurate method of machining linear graduations on a milling machine is to

a. gear an indexing head to the table transverse gage.
b. use the longitudinal feed screw graduated collar.
c. gear an indexing head to the table feed screw.
d. use the transverse feed screw graduated collar.

17. (411) A milling machine attachment which has degree graduations around its circumference is called

a. a high-speed universal circle attachment.
b. a circular milling attachment.
c. an indexing head.
d. a toolmaker's compass knee.

18. (411) What two milling machine attachments are designed primarily for increasing the capabilities of the index head?

a. The rack milling attachment and the right angle plate.
b. Raising blocks and the toolmaker's knee.
c. The right-angle plate and raising blocks.
d. The toolmaker's knee and the rack milling attachment.

19. (412) To machine a helix on a milling machine, you should cause the work to rotate

a. while it is aligned parallel to the cutter axis.
b. at the same time that it is fed longitudinally to the cutter.
c. while it is aligned perpendicular to the cutter axis.
d. at the same time that it is fed transversely to the cutter.

20. (413) All of the following types of gears can be bevel gears except for

a. a miter gear.
b. a gear and pinion set.
c. a worm gear.
d. two gears mounted on shafts at rights angles to each other.

21. (414) When a milling machine is installed in a shop, it should be leveled by placing a precision level

a. longitudinally on the table.
b. on the column bearing surface and transversely on the table.
c. transversely on the table.
d. as indicated in both options a and c.

22. (414) Which of the following milling machine adjustments would be the least likely to be required over a given period of operation?

a. A spindle bearing adjustment.
b. A gib adjustment.
c. A driving clutch adjustment.
d. A table feed screw bearing adjustment.

23. (415) You must machine a high finish on a horizontal flat surface of a rough machined part using the shaper. What cutting tool would be your best choice?

a. A roundnose.
b. A shear.
c. A shovelnose.
d. A squaring.

24. (416) The main thing to remember when switching a shaper tool bit from a common lathe-type toolholder to a swivel-type toolholder is that the tool bit

a. will be held at more than 14° angle of the other holder.
b. end relief angle should be decreased.
c. will be held at the same angle as in the other holder.
d. end relief angle should be increased.

25. (416) A type of workholding device that can be used in conjunction with a shaper vise to press thin work down tight against parallels and still leave the top surface clear for machining is called

a. holddown straps.	c. toe dog and bunters.
b. bunters.	d. clamps.

26. (417) In the shaper driving mechanism, the top end of the rocker arm which changes the rotating motion of the bull wheel to a reciprocating motion is connected

a. directly to the ram positioning mechanism inside the ram.
b. to a connecting link which connects to the bull wheel.
c. to a sliding block which connects to the ram.
d. to a connecting link which drives the ram.

27. (418) When you plane flat horizontal surfaces on a shaper, the direction of feed

a. should usually be from left to right.
b. of the toolslide should normally be toward the vise.
c. of the table should normally be away from the operator's side of the machine.
d. of the toolslide should normally be away from the vise.

28. (418) When you square the sides of a parallel on a shaper, where should side one (1st side machined) be positioned when side three (3rd side machined) is being machined?

a: Against the movable jaw of the shaper vise.
b. Against the parallels supporting the work.
c. Against the solid jaw of the shaper vise.
d. Against a shim between the work and the movable jaw.

29. (419) When you align a side finishing tool for finish planing a vertical surface, you should align the cutting edge

a. parallel to the surface to be finished.
b. at a 30° angle to the surface to be finished.
c. at a 45° angle to the surface to be finished.
d. perpendicular to the surface to be finished.

30. (420) When roughing material between two shoulders, the clapper box should be positioned

a. at a 10° angle in the direction of feed.
b. centrally and the toolholder set at a 10° angle.
c. at a 10° angle opposite the direction of feed.
d. centrally and the toolholder set vertically.

31. (421) If both ends of the external keyseat terminate on the shaft, you should first drill

a. two adjacent holes at one end of the keyseat.
b. one hole at one end of the keyseat.
c. one hole at each end of the keyseat.
d. two adjacent holes at one end of the keyseat and one hole at the other end.

32. (422) To plane angular surfaces with the shaper by simply swiveling the vise, the depth of cut is taken by

a. turning the toolslide handcrank and the feed is by power.
b. moving the table with the work touching the tool and feeding the tool vertically.
c. turning the toolslide handcrank and the feed is by hand with the table feed handcrank.
d. moving the table toward the tool and the feed is by power.

33. (423) Normally, the best method for planing several small convex surfaces on the shaper would be to

a. finish them with a roundnose tool by moving the work and toolslide simultaneously.
b. rough them out with a roundnose tool and finish them with a [illegible] tool.
c. finish them with a squaring tool to leave a fine finish.
d. rough them out with a roundnose tool and finish them with a side finishing tool.

34. (424) To properly level a shaper, a precision level should be placed

a. crosswise on the table and then lengthwise on the table.
b. lengthwise and then crosswise on top of the [illegible] [illegible].
c. crosswise on the table and then lengthwise on top of the column.
d. lengthwise on top of the column and then crosswise on the [illegible] of the toolslide.

35. (425) The purpose of a bond in a grinding wheel is to

a. control the hardness of the wheel.
b. hold the abrasive grains in place.
c. provide the proper wheel safety factor at operating speed.
d. do all of the above.

36. (425) The main difference between silicon carbide abrasives and aluminum oxides abrasives is that silicon carbide abrasives are

a. slightly softer and do not fracture as easily as aluminum oxides.
b. harder but do not fracture as easily as aluminum oxides.
c. harder and fracture more easily than aluminum oxides.
d. softer and fracture more easily than aluminum oxides.

37. (426) In the grinding wheel marking A60-L6-V11, what does the letter "A" designate?

a. The wheel grade.
b. The bond type.
c. The structure grade.
d. The abrasive type.

38. (427) To grind a piece of hardened tool steel and to obtain a fine finish, you should select a grinding wheel which has

a. a fine grain size.
b. a coarse grain size.
c. a hard grade.
d. an open structure.

39. (428) The diameter of the flanges for mounting a grinding wheel should be about what fraction of the diameter of the wheel?

a. 3/4 the diameter of the wheel.
b. 2/3 the diameter of the wheel.
c. 1/2 the diameter of the wheel.
d. 1/3 the diameter of the wheel.

40. (428) The most efficient type of grinding wheel dresser for truing wheels is the

a. diamond dresser. c. mechanical dresser.
b. abrasive stick dresser. d. abrasive wheel dresser.

41. (429) If the recommended grinding wheel sfpm for a grinding operation was 5500, but your calculated sfpm is only 5100, how could you increase it without changing the spindle rpm?

a. Choose a larger diameter grinding wheel.
b. Increase the size of the spindle.
c. Choose a smaller diameter grinding wheel.
d. Decrease the size of the spindle.

42. (430) In normal cylindrical grinding, the depth of cut is obtained by moving the

a. wheel toward the workpiece. c. wheel away from the workpiece.
b. workpiece toward the wheel. d. workpiece away from the wheel.

43. (431) When you are preparing to grind the blade of a [illegible] [illegible], you should take up the [illegible] of the

a. [illegible] point of [illegible] along the reamer length.
b. [illegible] point of [illegible] along the blade length.
c. [illegible] point of [illegible] along the reamer length.
d. [illegible] point of [illegible] along the blade length.

44. (432) You must remove a 0.001 TPI from the shank of a reamer you are grinding, so you mount a dial indicator so that its spindle contacts the table 20 inches from the table swivel point. How much should the table be moved at the indicator to remove the taper?

a. 0.001 inch. c. 0.010 inch.
b. 0.002 inch. d. 0.020 inch.

45. (432) When you grind a long conical taper between centers by swiveling the table, the axis of the work should be aligned

a. parallel with the line of motion of the table.
b. at an angle with the line of motion of the table.
c. parallel with the axis of the grinding wheel.
d. at an angle with the spindle, but parallel with the line of motion of the table.

46. (432) During an internal grinding operation, what condition that is more pronounced in internal grinding, causes the grinding wheel to load quickly?

a. The faster table movement. c. The slower cutting speeds.
b. The springing of the quill. d. The large area of contact.

47. (433) When you perform face grinding operations on the grinder, the most desirable method is the

a. straight wheel method. c. angular wheel method.
b. cup wheel method. d. double-angled wheel method.

48. (433) Extremely light cuts should be taken when form grinding to prevent

a. grinding cracks from developing in the work.
b. the side of the wheel from being worn too quickly.
c. burning the work.
d. both options a and c.

49. (434) On the rotating table type of surface grinder, the depth of cut is obtained by feeding the

a. work downward into the wheel.
b. wheel upward into the work.
c. work upward into the wheel.
d. wheel downward into the work.

50. (435) [illegible]

a. [illegible]
b. [illegible]
c. [illegible]
d. [illegible]

51. [illegible]

a. [illegible]
b. [illegible]
c. [illegible]
d. [illegible]

52. (437) When you grind form cutters to sharpen the teeth, you should grind

a. the face of the teeth.
b. the primary clearance angles only.
c. both the primary and secondary clearance angles.
d. the secondary clearance angles only.

53. (438) The headstock and work head are both grinding machine attachments, but the work head is

a. for holding work while the headstock supports the grinding wheel.
b. not powered while the headstock is.
c. powered while the headstock is not.
d. for holding work stationary only.

54. (439) If the coolant in a grinding machine is not changed when it becomes dirty or rancid, it can result in

a. an unbalanced grinding wheel.
b. clogging of the various hydraulic lines.
c. damage to the coolant pump.
d. all of the above.

55. (440) On grinding machines equipped with plain spindle bearings, wear can be compensated for by

a. spring loaded shoes which work automatically.
b. preloaded precision ball bearings.
c. adjusting several set screws extremely carefully.
d. both options a and c.

56. (441) Which of the following would not be a likely cause of heat discoloration on the surface of work being ground in a grinding machine?

a. Wheel incorrectly positioned in relation to the work.
b. Incorrect spindle speed.
c. Inadequate, dirty, or gummy coolant.
d. Excessive feed.

57. (442) A nondestructive method of inspection that discloses structural soundness and assembly is called

a. eddy current.
b. radiography.
c. magnetic particle.
d. fluorescent penetrant.

58. [illegible]

a. [illegible]
b. [illegible]
c. [illegible]
d. [illegible]

59. [illegible]

a. [illegible]
b. [illegible]
c. [illegible]
d. [illegible]

60. [illegible]

a. honing.
b. filing.
c. polishing.
d. scraping.

61. (446) A type of operation in which abrasive particles are held in suspension between the work and a metal tool is called

a. grinding.
b. honing.
c. lapping.
d. polishing.

62. (446) When you lap external cylindrical work with a ring lap, the abrasive compound should be

a. put on the inside of the lap as needed by removing it from the work.
b. fed into the lap through either end.
c. put on the surface of the work after the lap has been removed.
d. fed into the lap through the full length side split.

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 44 USC 3101. PRINCIPAL PURPOSE(S): To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with every ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA: MAIL TO ECI, GUNTER AFS, ALA 36118

1. THIS REQUEST CONCERNS COURSE
2. TODAY'S DATE
3. ENROLLMENT DATE
4. PREVIOUS SERIAL NUMBER
5. SOCIAL SECURITY NUMBER ☐☐☐ – ☐☐ – ☐☐☐☐
6. GRADE/RANK
7. INITIALS ☐ ☐ LAST NAME
8. OTHER ECI COURSES NOW ENROLLED IN
9. ADDRESS: (OJT ENROLLEES - ADDRESS OF UNIT TRAINING OFFICE/ALL OTHERS - CURRENT MAILING ADDRESS)

ZIP CODE ☐☐☐☐☐

10. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE:
11. AUTOVON NUMBER
12. TEST CONTROL OFFICE ZIP CODE/SHRED

SECTION II: Old or INCORRECT ENROLLMENT DATA

1. NAME: 2. GRADE/RANK: 3. SSAN:
4. ADDRESS: 5. TEST OFFICE ZIP/SHRED:

SECTION III: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an "X" through number in box to left of service requested)

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. The latest course workbooks have a Form 17 printed on the last page.

1. EXTEND COURSE COMPLETION DATE. (Justify in Remarks)
2. SEND VRE ANSWER SHEETS FOR VOL(s): 1 2 3 4 5 6 7 8 9 - ORIGINALS WERE: NOT RECEIVED, LOST, MISUSED
3. SEND COURSE MATERIALS (Specify in remarks) - ORIGINALS WERE: NOT RECEIVED, LOST, DAMAGED.
4. COURSE EXAM NOT YET RECEIVED. FINAL VRE SUBMITTED FOR GRADING ON (Date):
5. RESULTS FOR VRE VOL(s): 1 2 3 4 5 6 7 8 9 NOT YET RECEIVED. ANSWER SHEET(s) SUBMITTED ON (Date):
6. RESULTS FOR CE NOT YET RECEIVED. ANSWER SHEET SUBMITTED TO ECI ON (Date):
7. PREVIOUS INQUIRY (ECI FORM 17, LTR, MSG) SENT TO ECI ON:
8. GIVE INSTRUCTIONAL ASSISTANCE AS REQUESTED ON REVERSE:
9. OTHER (Explain fully in remarks)

REMARKS: (Continue on Reverse)

OJT STUDENTS must have their OJT Administrator certify this request.

ALL OTHER STUDENTS may certify their own requests.

I certify that the information on this form is accurate and that this request cannot be answered at this station. (Signature)

ECI FORM 17 JUN 77 PREVIOUS EDITIONS MAY BE USED

BEST COPY AVAILABLE

SECTION IV: REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of textual material should be forwarded directly to preparing agency. **Name of agency can be found at the bottom of the inside cover of each text.** All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:

MY QUESTION IS:

Course No. ___________

Volume No. ___________

VRE Form No. __________

VRE Item No. __________

Answer You Chose (Letter) __________

Has VRE Answer Sheet been submitted for grading?

☐ YES ☐ NO

REFERENCE
(Textual support for the answer I chose can be found as shown below)

In Volume No: _________

On Page No: __________

In_____ (Left)_____(Right) Column

Lines_____Through______

Remarks:

53150 04 7704

CDC 53150

MACHINIST

(AFSC 53150)

Volume 4

Tool Design and Shop Management

Proficimus More Irretenti

Extension Course Institute

Air University

Prepared by
MSG Teddy L. Ford
3340 Technical Training Group
USAF School of Applied Aerospace Sciences (ATC)
Chanute AFB, Illinois 61868

Reviewed by
Daniel H. McCalib, Education Specialist
Extension Course Institute (AU)
Gunter AFS, Alabama 36118

PREPARED BY
3340 TECHNICAL TRAINING GROUP
USAF SCHOOL OF APPLIED AEROSPACE SCIENCES (ATC)
CHANUTE AIR FORCE BASE, ILLINOIS

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

CONGRATULATIONS! You have made it to the last volume of this Career Development Course. But don't let up yet. This volume contains some very important information that you need to round out your studies in preparation for the award of the 5 level. Chapter 1 examines the techniques of tool design and fabrication. Chapter 2 covers technical publications, and Chapter 3 covers supervision and training. And, finally, in Chapter 4, we examine the various aspects of maintenance management.

Please note that in this volume, we are using the pronoun *he, his,* and him in its generic sense, not its masculine sense. The word to which it refers is person.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOX, Chanute AFB IL 61868. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of September 1976.

Contents

Page

Preface .... *iii*

Chapter

1 Tool Design and Fabrication 1

2 Technical Publications 29

3 Supervision and Training 40

4 Maintenance Management 59

Bibliography 72

Answers for Exercises 73

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Tool Design and Fabrication

IF YOU HAVE ever watched a skilled surgeon operate, you noted that he used each tool strictly for its intended purpose. As a skilled machinist, you too much use each tool for its intended purpose. However, you have one advantage that the surgeon doesn't have. You have the capability to change the design of a tool from time to time as the need arises or to fabricate an entirely new tool to meet a specific requirement. In this chapter, we will examine some methods and practices that you should follow when you design and fabricate special tools, jigs and fixtures, and dies.

1-1. Special Tool Design and Fabrication

The design and fabrication of practical tools are important tasks of a machinist. Some tools are simple and quite easy to develop. Others are complicated and require more careful development. A tool can be defined as "any device that is capable of working a material into a desired shape, holding a material while it is being worked, or measuring it after the work is completed." In the Air Force, as well as in industry, tool design and fabrication are important processes that are necessary for the economical production of parts. In this section, we will discuss fastening devices and heat-treating requirements in the design and fabrication of special tools. Also, we will examine some special tool characteristics as well as material and machining requirements.

600. Clarify the characteristics and uses of such fastening devices as bolts, screws, nuts, and pins and, given a hypothetical situation, specify the screw type to use.

Fastening devices are *bread and butter* to a machinist. This includes bolts, screws, nuts, and pins, discussed in that order here.

Fastening Devices. You should, whenever possible, use standard fastening devices and bearings in the construction of any item that you design. Standard parts are usually readily available. Consequently, the number of parts to manufacture and the cost of the item is usually reduced. Knowing about the fastening devices spoken of here will help you select the proper types of such devices and bearings in manufacturing the tool that you are designing. Again, among the many types of fastening devices, the most common are those already mentioned: bolts, screws, nuts, and pins.

Bolts. Bolts are used with nuts and threaded holes to fasten parts together. Some of the more common types of bolts are as follows:

a. Aircraft bolts, which are specifically designed to be used on aircraft. Markings on these boltheads indicate the type of material that each bolt is made of and whether or not it is a special or a close tolerance bolt. Figure 1-1 shows the markings on the head of an aircraft bolt and typical dimensions and tolerances.

b. Capscrews are available in diameters of 1/4 to 1 inch and in lengths of 1/2 to 6 inches. They are made of steel or brass. The longer capscrews can be used with nuts, but they are usually used to fasten parts to other parts that have threaded holes.

c. Socket head capscrews are used for the same purposes as common capscrews. Instead of hexagonal, however, the head of a socket head capscrew is round and has a hexagonal socket. Hexagonal or Allen wrenches are used to tighten and loosen socket head capscrews. The heads normally fit into counterbored holes in the part being fastened.

d. Setscrews are used to fasten parts, such as pulleys, gears, etc., to shafts. They are usually hardened. Setscrews have slotted heads, square heads, or socket heads.

e. Machine bolts are available in a variety of sizes. They are usually used with nuts to fasten parts together. They have either square or hexagonal heads and are made of steel or brass.

f. Carriage bolts have round heads above a square section. The square section pulls into the wood and keeps the bolt from turning when the nut is tightened.

g. Stove bolts have slotted round or flat heads and are available in diameters of 1/8 to 1/2 inch and in lengths of 3/8 to 6 inches.

h. Studs are bolts threaded on both ends. One end, usually the coarse-threaded end, is threaded into the parent part of a mechanism and another part is fastened to the fine-threaded end by means of a nut.

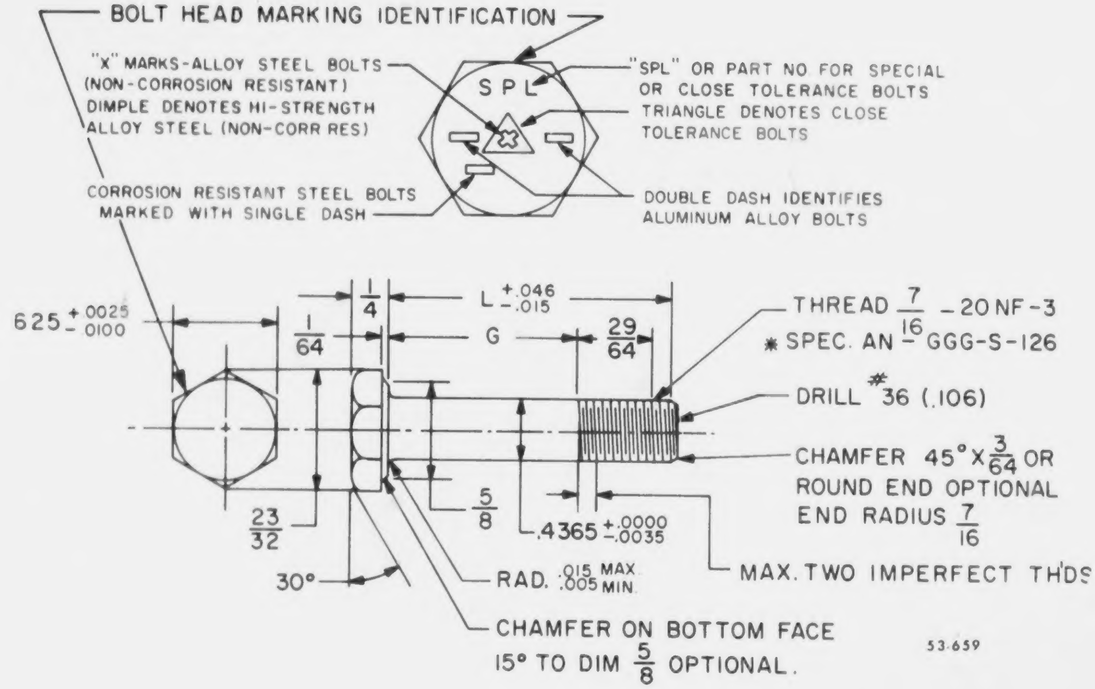

BOLT HEAD MARKING IDENTIFICATION
"X" MARKS-ALLOY STEEL BOLTS (NON-CORROSION RESISTANT)
DIMPLE DENOTES HI-STRENGTH ALLOY STEEL (NON-CORR RES)
SPL
"SPL" OR PART NO FOR SPECIAL OR CLOSE TOLERANCE BOLTS
TRIANGLE DENOTES CLOSE TOLERANCE BOLTS
CORROSION RESISTANT STEEL BOLTS MARKED WITH SINGLE DASH
DOUBLE DASH IDENTIFIES ALUMINUM ALLOY BOLTS
625 +.0025 -.0100
1/4
1/64
L +.046 -.015
G
29/64
THREAD 7/16 - 20 NF-3
* SPEC. AN - GGG-S-126
DRILL #36 (.106)
CHAMFER 45° X 3/64 OR ROUND END OPTIONAL END RADIUS 7/16
23/32
5/8
.4365 +.0000 -.0035
MAX. TWO IMPERFECT TH'DS
30°
RAD. .015 MAX .005 MIN
CHAMFER ON BOTTOM FACE 15° TO DIM 5/8 OPTIONAL.
53-659

Figure 1-1. Bolt markings.

Screws. The screw is a common form of threaded fastening device. Screws are usually identified by the shape of the screwhead. Sheet metal screws are made of hardened steel and are threaded directly into holes drilled in sheet metal. The heads of sheet metal screws are usually round or flat. Machine screws are made of steel, brass, or aluminum alloy. Machine screws are designed to be threaded into a tapped hole or to be used with a nut. Some of the types of machine screws are given below:

a. Fillister head screws, which are commonly used in light mechanism assemblies and are available with or without a drilled head.

b. Flathead screws, which are used in countersunk holes. They provide a surface face free of projections and are used for streamlining.

c. Roundhead, button head, and washer head screws, which are used where the projection head is not objectionable. The washer head has a large contact area on the head.

d. Phillips screws and Reed and Prince screws, which have cross-slot type heads. A Phillips screwdriver must be used with Phillips screws, and a Reed and Prince screwdriver is used with Reed and Prince screws.

Nuts. A nut is threaded internally to mate with the threads of a bolt, screw, or stud. The threads of a nut must correspond to the external threads to eliminate jammed or stripped threads. Nuts are made of steel, aluminum alloy, or brass. Among the more common are these:

a. Plain aircraft, or hexagon nuts, which have a limited use in aircraft and require a locking or safety device, such as a check nut or lockwasher.

b. Check nuts, which are thin nuts used as a locking device for nuts, setscrews, threaded rod ends, and other devices.

c. Castle nuts, which are used with bolts that have a drilled hole in the threaded end to receive a cotter pin or lock wire for safetying.

d. Shear nuts, which are used with such devices as clevis bolts, in which there is no tension on the bolt.

e. Plain and slotted engine nuts, which are high-strength nuts and are designed for use on engines. They require a locking device.

f. Locknuts, which are used for locking all external engine nuts, except those used with safety wire or a cotter pin.

g. Wingnuts, which are used where the desired tightness can be obtained with the fingers.

h. Fiber insert nuts, which are the most common of the self-locking nuts. They have a fiber insert that is smaller in diameter than the bolt. When the nut is threaded on a bolt, the fiber insert expands, as shown in figure 1-2, and tightens the nut on the bolt. The fiber insert nut should not be used in a location subjected to rotational movement or near excessive heat (i.e., above 250° F).

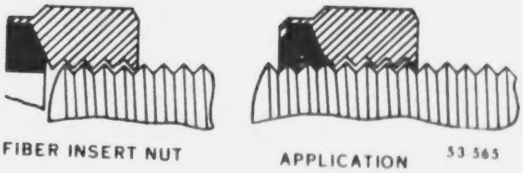


Figure 1-2. Fiber insert nut.

Pins. The three types of pins, shown in figure 1-3, that are most frequently used in assemblies are flathead, taper (plain and threaded), and straight pins. They differ as follows:

a. Flathead pins, commonly called *clevis pins,* which are made of steel and are used on tie rod terminals or on secondary controls. The pin is safetied with a cotter pin.

b. Taper pins, which are used to pin or to connect two parts, such as the hub of a part to a shaft, where it is essential to eliminate any looseness or play. They are made of steel and some taper pins have a hole in the large end to receive safety wire. The common plain taper pin does not have a drilled hole in the large end. Another common use of the taper pin is to align parts in an assembly. Threaded taper pins are used for the same purposes as are common taper pins, when a more positive means of securing the pin is required. Threaded taper pins are frequently used for fastening aircraft parts. A taper pin washer and a nut are used with threaded taper pins.

c. Straight pins, which are used primarily to fasten or secure mating parts and to align parts.

Exercises (600):

1. Tell why you should strive to use standard parts whenever possible when manufacturing parts.

2. Give the head marking of an aircraft bolt which indicates that it is a close tolerance bolt.

3. Differentiate between a common capscrew and a socket head capscrew.

4. *Situation:* a part must be designed with a smooth surface. Name the style of screw which should be used to secure a panel to this surface.

5. Cite the conditions that would prevent the use of a fiber insert nut in an assembly.

6. State the purpose of taper pins.

601. Clarify significant aspects of the relationship between the design and the heat-treatment of a machine part.

Because the relationship between tool design and its heat-treatment is a significant one, the key aspects of which you, a machinist, must know to do even an adequate job, we will study it next.

Tool Design and Heat-Treatment. As you may recall from our discussion of heat-treating processes in Volume 2 of this CDC, heat-treating is a series of

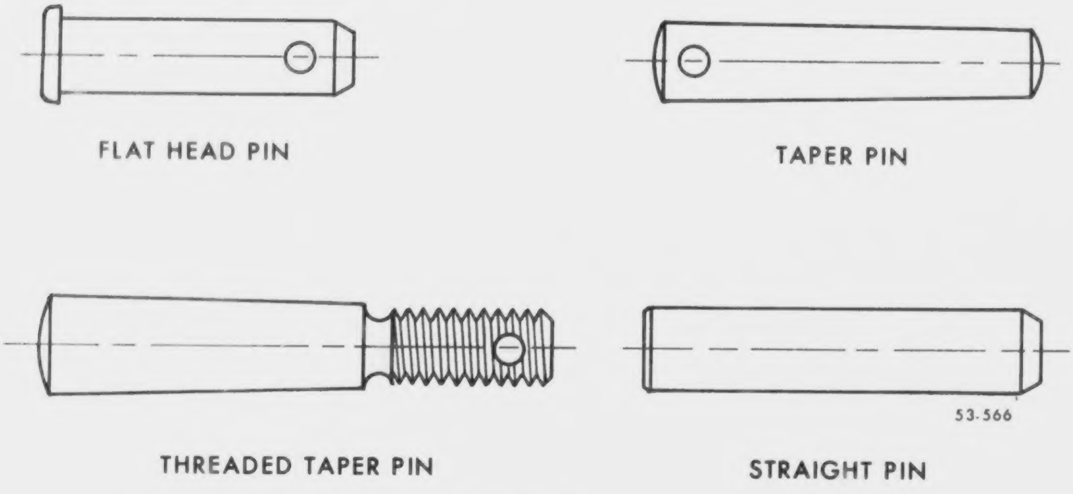


Figure 1-3. Pins.

operations involving the heating and cooling of metals in the solid state. Its basic purpose is to change a metal's mechanical property or a combination of mechanical properties, so that the metal will be more useful, serviceable, and safe for a definite purpose. Heat-treating can make a metal harder, stronger, and more resistant to impact. It can also make a metal softer and more ductile. However, no one heat-treating operation can produce all of these characteristics. In fact, some properties are often improved at the expense of others. As a result of hardening, for example, a metal becomes brittle.

To repeat, as a machinist, you should know the effects of heat-treating and the results that you can expect from each heat-treating operation. In many cases, for example, the metal and the heat-treatment are specified. Here, make no substitutions of materials unless the substitution is authorized by technical orders or other authoritative sources. In other cases, you may have to specify the heat-treating process. If so, you must consider both (1) the use to which the part will be put and (2) the mechanical properties required. If you overlook the design of the part or the metal of which it is made, the part may warp badly or crack, or the required mechanical properties may not be obtained during heat-treatment.

The rate of cooling is affected not only by the difference in mass or size but also by the shape and the surface finish involved. Accordingly, when a part is removed from a furnace to be quenched, even though it is uniform in its cross section, its shape may cause uneven cooling to occur. This means that you need to give attention to contour in order to avoid such abnormalities. That is, you should avoid having or allowing protruding corners on parts, such as angle plate and V-blocks, whenever possible, by slightly rounding corners and edges. Design affects the serviceability of a tool or machined part. In fact, the failure of a part can, in most cases, be traced to improper design or to improper heat-treating procedures. Figures 1-4 and 1-5 illustrate good and poor part design. Improper design or heat-treatment of a part can cause cracking, warping, or internal strains, all of which render a part unfit for service.

Two forces that may combine to break steel apart are (1) the residual stresses set up during machining operations and (2) the heat treatment of the part. There is also the forces applied to the part when it is put into service. Internal stress in a part can equal as much as 90 percent of its strength and, therefore, can cause it to break under a comparatively small load.

The most serious cause of residual stress is the hardening operation. The right method of cooling depends not only upon the chemical makeup of the metal but also upon the size and shape of the part. The failure of a part is usually caused by the use of a design without any consideration for the heat-treatment or for the use of the part. Designs with abrupt changes in mass or size, will, when quenched, set up massive stresses in the part and will cause warping. Other parts, even if they are heat-treated satisfactorily, will fail in use if they are improperly designed.

Errors in design not only cause residual stress in a part but they can also cause a concentration of stress, which, when combined with service stresses (the stresses caused by an actual load in use), can cause the part to fail. Some designs are almost impossible to harden because of the part's change in size. Shape angles and uneven balance of mass concentrate stress.

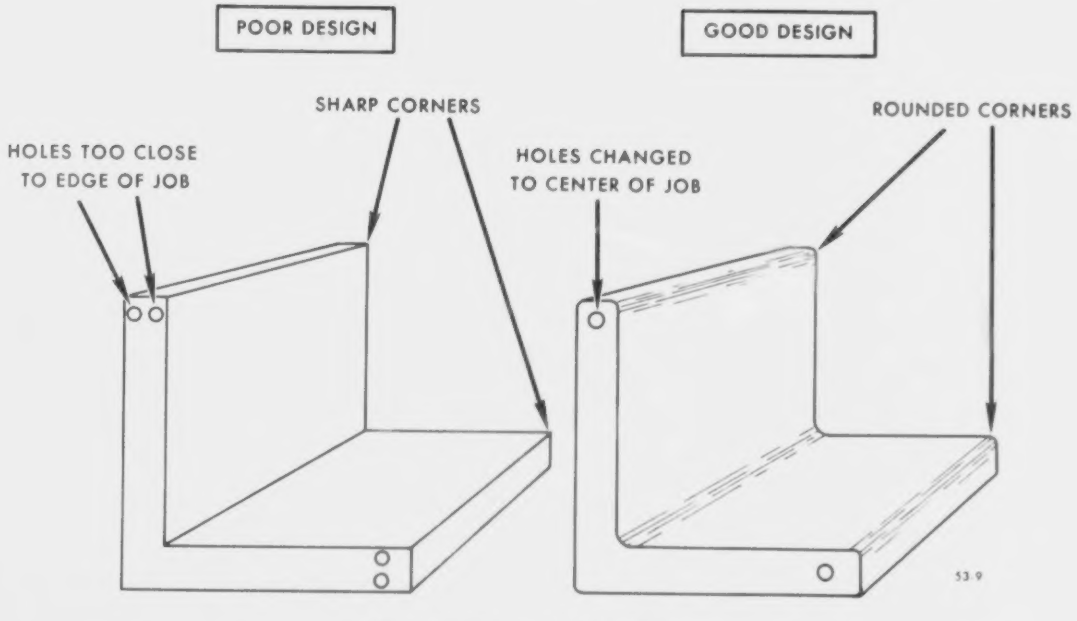

POOR DESIGN
GOOD DESIGN
SHARP CORNERS
HOLES TOO CLOSE TO EDGE OF JOB
HOLES CHANGED TO CENTER OF JOB
ROUNDED CORNERS
53.9

Figure 1-4. Corner and fillet design.

A piece, properly designed in relation to heat-treatment, heats and cools evenly. Perfection in this respect is unattainable, because the surface of a well-balanced part cools faster than does the center. Understanding all of this, a machinist should design a part so that it will cool as evenly as possible and will have a low concentration of stress under load.

Exercises (601):

1. Give the purpose of heat-treatment.

2. Cite briefly the possible results of overloading the metal that a part is made of when it must be heat-treated.

3. Tell how the mass and surface finish of a part affects the heat-treatment of it.

4. State the metal condition that can cause a heat-treated part to break under even a very light load.

5. Indicate the type of design that makes it extremely difficult to properly heat-treat a part.

602. Give the steps in tool planning and the information learned in determining a tool's functions, the purpose of a gage, and requirements for various gage types and, given a hypothetical situation involving an inspection ring gage set, state the NOT GO gage's bore diameter.

Tools and special gages are important to machinists, obviously. They are this section's subjects.

Tool Planning. In every operation, the tools must be adapted to the material, the machine, other tools, and the operator. When you choose a machine for an operation, its capacity and range are important items to consider. After you have selected the machine, the tools that you use on it must perform well on that particular machine. For example, on a milling machine, the length to be machined must fall within the travel of the table, and provision must be made for mounting the tools. The tools must have enough bulk and backing to prevent their destruction during a machining operation.

Tool planning is concerned with the processes to use, the operations required, and the locating points for each operation. It also involves the dimensions and tolerances to be held and the machine tools needed to make the part. Tool planning must be thorough and usually involves the following steps:

1. Determine what the tool must do. This step tells you what type of tool you need, what operation it is to perform, and how it must be held or fastened to the machine.

2. Select or invent a device to meet the requirements. Your knowledge of the tools and holding devices that are available from standard sources will be of great value at this point. If there are none available, then you must invent your own tools for this purpose.

3. Construct the device to perform the required task most efficiently. When you have decided upon a general form of tool, you must arrange and position it to do a specific job. Consider these main ideas at this time: economy, kind of operation, accuracy, and safety.

Designs of Special Gages. Modern machine work requires extensive use of gages for shop inspections and references. A gage is defined as a device for determining whether or not the dimensions of a manufactured part are within specified limits.

There are many types of gages, such as ring, receiving, plug, pin, snap, thread, and form gages. Each of these types is used to check a particular shape or part and must, therefore, be designed and fabricated to exacting specifications. If the gage is not accurate, you could never use it to check the accuracy of machined parts. If gages are to be accurately fabricated and are to maintain that accuracy, they must be made of the proper materials and in relation to tolerance requirements of the parts that the gages must check.

Materials used in gages. The types of steels used for gages are machine steel, plain carbon steel, and special alloy steels, with machine steel used most often. The carbon content of machine steel for gages usually ranges from 0.15 to 0.25 percent, although it may be as high as 0.50 percent, especially for ring or plug gages. A 0.20 percent carbon steel, containing 1.00 percent manganese and about 0.05 percent phosphorus and sulphur, is considered very satisfactory. This general class of steel is most commonly used for snap

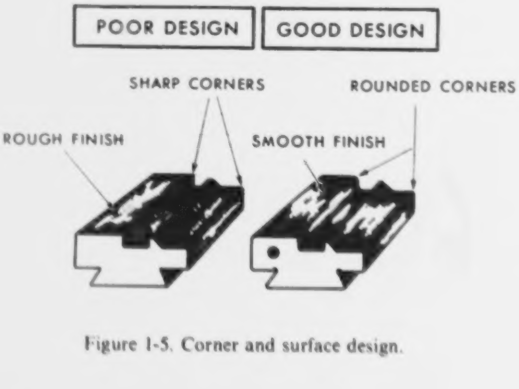


Figure 1-5. Corner and surface design.

gages. Steel for snap gages should not contain silicone, however, since this causes warping in the hardening operation. Plug gages, ring gages, and other forms that can be ground easily after hardening are often made of steel containing about 0.50 percent carbon.

High carbon steel is sometimes preferred to machine steel because it can be hardened in much less time than is required for carburizing and hardening machine steel gages. The high carbon steel used for gages usually contains about 0.90 percent carbon. Special alloy steels have been developed, which are adapted to fine gage work partly because changes due to hardening are very slight.

Gage tolerance. There are two classes of gages that you would normally design and fabricate: working and inspection. Of these, working gages are used to check parts during fabrication. In contrast, inspection gages are used to inspect parts after they have been completed. Inspection gages are required principally because working gages tend to wear faster. The reason for such fast wearing out is that working gages are used more often. The size of a gage is determined by the tolerance of the part to be gaged. According to the practice of the more prominent manufacturers of gages, a tolerance of 10 percent of the work tolerance is generally allowed on ordinary working and inspection gages. For example, if you were to make a *GO* and *NOT GO* ring gage set to gage a 1.00-inch diameter shaft and the tolerance of the shaft was plus or minus 0.005 inch, the tolerance of the gages would be 0.0005 inch for both working and inspection gages. This amount is subtracted from the maximum size of the shaft and added to the minimum. There is, however, a difference between the minimum and maximum size of working and inspection gages. That difference is this: the minimum size of the working gages is 10 percent of the tolerance larger than the minimum size of the inspection gages. By comparison, the maximum size of the working gages is made 10 percent of the tolerance smaller than the maximum size of the inspection gages. Therefore, in our example, the dimensions and tolerances of the working gage set would be:

GO gage bore = 1.0045 +.0000
.0005
NOT GO gage bore = 0.9955 +.0005
.0000

The inspection gage set would be:

GO gage bore = 1.0050 +.0000
-.0005
NOT GO gage bore = 0.9950 +.0005
-.0000

The reason for this difference is that, if the working gages and the inspection gages were made the same size, the working gages, which wear faster, would become larger than the inspection gages.

Exercises (602):

1. List the steps usually involved in tool planning.

2. Provide the important information that you can obtain, when you are planning for a tool, by determining what the tool must do.

3. Give the purpose of a gage.

4. Name any five of seven types of gages.

5. Cite the main elements in the steel used most commonly for manufacturing snap gages.

6. Clarify why a higher carbon content is more acceptable in plug and ring gages than in other types of gages.

7. State the possible advantage of using special alloy steels when designing a gage.

8. *Situation:* you are designing a GO and NOT GO inspection ring gage set to check a 1.5-inch diameter shaft with a tolerance of + .002 - .002. Tell what the bore diameter of the NOT GO gage should be.

9. Indicate why working gages should be designed with slightly less total tolerance than inspection gages.

603. List uncommon materials used in making punches and dies and clarify selected properties of such materials and their applications in fabricating tools such as punch and die sets.

Where would machinists be without adequate knowledge of tool materials applicable to the fabrication of such tools as punch and die sets? The answer is, they would be in trouble. This, then, is taken up in this part of this volume.

Tool Materials. It is clear that the material from which a tool is made is the most critical factor in its fabrication. For this reason, tool design engineers, through years of experience and trial and error, have set up standards for fabricating most cutting tools, such as lathe tools and milling cutters, and for most handtools. For purposes of this section, we will center our discussion on the punch and die manufacture. It is unfortunate that the many variables in the design and fabrication of punches and dies make it impossible for authorities to recommend specific standards. Still, there are certain factors that must be considered in the manufacture of all punch and die sets.

The many materials from which punches and dies can be constructed include zinc alloys, rubber, and thermosetting phenolic and epoxy plastic. Most die sets, however, are made of steel in one of its many forms.

Plain carbon steel. Plain carbon steel is the least expensive of all steels and the most widely used. Its carbon content ranges from about 0.7 to 1.5 percent. This steel is sometimes modified for some uses by the addition of small amounts of chromium and vanadium. Although they are frequently used in the manufacture of tools, carbon steels are prone to be erratic in their response to heat-treatment. This is due largely to their differences in grain size and ability to harden. Even steels of the same composition and steels made by the same manufacturer are similarly erratic.

Nondeforming tool steel. Nondeforming tool and die steels are used extensively for intricately shaped tools, where heat-treating distortion must be held to a minimum. These steels generally contain substantial amounts of manganese—about 1.5 to 1.75 percent. The manganese content is lower when chromium and tungsten are added. With the proper proportions of alloying elements, this type of tool steel can possess good hardening quality and resistance to wear.

High-speed tool steel. High-speed steels contain large amounts of tungsten and smaller amounts of chromium, vanadium, and in some cases, molybdenum and cobalt. They are valuable in the manufacture of cutting tools, because they retain hardness and strength at high-operating temperatures. This type of tool steel, when properly heat-treated, is hard and has good strength.

Nonferrous tool materials. Nonferrous tool materials include such metallic elements as tungsten, tantalum, titanium, columbium, and cobalt in their carbide forms. These materials can be used for machine tools for blanking, drawing, shaping, and spinning dies, as well as for many other applications. Tools made of these materials perform beyond the limits of steel tools and are quite suitable for use on hard, abrasive materials and hard alloys. The hardness that can be attained by heat-treating these materials is much higher than can be attained in tool steels by any known method of heat-treatment.

Exercises (603):

1. List some of the more uncommon materials used in manufacturing punches and dies.

2. Name the type of steel used most in fabricating punch and die sets.

3. Cite the property of plain carbon steel that is a disadvantage when used to make a punch and die set.

4. Relate briefly the desirable properties of nondeforming tool steel, specifying the application to which it is best suited.

5. Identify the type of material best suited for making a punch and die set that must be able to retain its hardness and edge at high operating temperatures.

6. Give the advantage that nonferrous tool materials have over tool steels.

604. Analyze the factors to consider when selecting materials and determining machining requirements for fabricating special tools and, given hypothetical situations, indicate why the machine used is important or the reason for planning the operations arrangement used.

In addition to tool materials, machinists need to understand material selection and machining requirements for making special tools. These are subjects of this section.

Material Selection. When you are designing or manufacturing a tool, you should consider several factors in selecting the materials. These include (1) the tool's use, (2) tool wear, (3) tool deflection, (4) thermal expansion, and (5) load on tools.

Use of the tool. The use of each tool is the main factor which governs the selection of the material from which it should be made. For example, milling cutters should be made of highly refined tool steel that has been tested for both internal and external defects.

Such defects in the material used constitute one of the most important causes of tool breakdown. Therefore, use only materials that can withstand the forces to which they will be subjected. You will usually find material defects in low-grade steels. This is not surprising, though, since the manufacturer did not intend for these steels to be used in fabricating tools and machines. Many defects in low-grade steels are caused by the manufacturing process itself, such as seams, laminations, blowholes, erratic grain size, and uneven tensile strength. Knowing these things, you should select only high-grade materials for such tools as jigs, fixtures, die sets, and cutting tools. Why? Because high-grade steels are made specifically for items of this type. Accordingly, the manufacturers have been very critical in the refinement of the high-grade tool steels. However, you should be aware of the remote possibility that even the best tool steel may have a defect.

Assume for a moment that you are fabricating a die set for a production run of several thousand parts, and you have selected a very high grade of tool steel. Here you would be wise to have the material tested for defects by the personnel of a nondestructive inspection laboratory. You can minimize tool breakdown by selecting the proper tool material and having the material tested before you use it.

Wear on tools. Wear causes tools to become inaccurate. For this reason, you should always use hard, wear-resistant materials in areas subject to wear, such as on jigs, fixtures, and gages. Also, keep the wearing surfaces as small as possible without sacrificing durability. Such small surfaces are also easier to keep clean and are cheaper to build. A good example of the effect of wear may be seen in a drill bushing in a drill jig. This type of bushing is subjected to abrasive wear from the revolving drill bit. Thus, if the drill bushing is too soft or made of improper material, even normal usage will cause it to wear and become inaccurate. But you can minimize this wear by using a material that can be heat-treated to an extremely hard state.

Tool deflection. Tool deflection is usually present in machining operations. Certainly, it cannot be eliminated totally. Yet it *can* be reduced to a minimum. Consider, for example, a dull tool—this causes several times as much deflection as does a sharp tool. Forces that cause deflection come from handling, clamping, and cutting actions. Moral: When you design and manufacture cutters, jigs, or fixtures, provide ample support for the tool and use a material of sufficient strength to withstand the desired cutting force. This approach will reduce the problem of deflection to a minimum.

Thermal expansion. Thermal expansion must be taken into consideration, especially when you are machining or holding dissimilar metals. For example, aluminum expands about twice as much as steel for every degree of change in temperature. The best way to keep thermal expansion to a minimum is to keep the tools sharp and to use an ample volume of coolant. When making a tool, choose a material that will retain its cutting edge during the required machining operation.

Load on tools. The type of load to which a tool will be subjected is a prime consideration. Two general considerations are involved in load. First, you must determine whether the machines or tools involved are capable of withstanding known external loads without failure. Second, you must determine the size and shape of a tool that can withstand the known external load forces.

Machining Requirements. Another area of prime consideration in fabrication is the determination of machining requirements. You will be faced constantly with problems of machining methods and procedures. Whether or not you are working from your own or another's design, you must determine the machining operations and how best to perform them. Accordingly, you should, first, study the design and the parts to be produced. Here you must fix thoroughly in your mind the function that the completed tool is to perform. Knowing this, before you start fabrication, develop a plan of machining requirements. The following are areas to consider and should help you develop your plan.

Materials, parts, and tools list. A material and parts list is usually a part of the design or drawings. However, before proceeding you should check this list or make a new list to make sure that the material and parts you need are available. Also, you need to know what hand and measuring tools are available to you. You can then act to acquire these materials and tools. Also, if you find that all of the listed materials and parts are not available, you may be able to use suitable substitutes. In the absence of the required tools, you may be able to improvise or to use alternate methods or techniques.

Machining methods and techniques. This is a vital area of consideration. Economy and quality of workmanship often depend upon the methods and techniques used. As you have probably found, usually several ways exist to perform a certain machining operation. Any one of these ways may be sound and good shop practice. But there is usually a *best* method for performing an operation under certain given conditions. Consider, for example, drilling, boring, and reaming—all of which can be done on a drill press, a lathe, or a milling machine. This being so, you must decide which of these machines and which of these techniques is best for a given situation. Thus, if hole location is not critical and several holes are to be machined, you can use a drill press to advantage. If hole location is critical? Here you can use the milling machine feed screw dials to great advantage. Again, what if large holes are to be bored, recessed, and threaded? For these actions you can use the lathe to advantage.

As far as is practical, you should group and perform all similar machining operations at the same time. This practice keeps work and tooling setup time to a minimum. Thus, if you find that you have a number of flat pieces to machine and planing is the best method to do this, perform the planing operation on as many pieces as possible while you are at the shaper. On the other hand, if milling is the best approach, perform as many milling operations as possible while you are at the milling machine. Also, you should perform machining operations on mating parts in pairs and at the same time, when practical. This technique insures accurate location and alignment when the parts are assembled.

Your machining requirements plan should be brief, yet complete. It should be legible and understandable to fellow workers and helpers. It should contain notes or references to the publications, such as TOs, manuals, and machinist handbooks, that you may need to use. In short, your plan should enable you to accomplish an economical and quality job.

Exercises (604):

1. Cite the main factor you should consider when you are selecting the material for making a tool, telling why this is your main consideration.

2. Tell the effect the wear factor has on the selection of tool materials.

3. Indicate the problems that can arise from a fabricated milling cutter when the selected tool material will not maintain a sharp cutting edge during its operation.

4. Specify what—before you actually begin machining a certain tool—you should do first, giving the reason for acting this way.

5. *Situation:* You must drill and ream four holes of various sizes in a part, and the work can be accomplished in a lathe, a milling machine, or a drill press. Clarify why it makes a difference which machine you use, and what this saves.

6. Situation: You must machine a tool that will include several different lathe and milling machine operations. Relate how you should plan the arrangement of these operations, giving the reason for your action.

1-2. Jig and Fixture Design and Fabrication

The primary purpose in the design and manufacture of jigs and fixtures is to align the tool and the workpiece properly during machining operations. Jigs and fixtures usually have some type of device for guiding, supporting, clamping, or gaging, to insure the accurate production of parts.

By using jigs and fixtures, we can reduce the cost of parts manufactured in large quantities. There is great advantage in employing jigs and fixtures when the interchangeability and accuracy of the finished products are important factors. In some cases, we can even justify using jigs and fixtures in low or limited production jobs if extreme accuracy can be achieved only by such use. One of their greatest advantages is that relatively unskilled labor can accomplish the job using these special tools.

Jigs and fixtures are so closely related that the terms are often confused. The term "jig" should be applied to those devices that hold, support, and locate a workpiece while they guide the cutting tool. The term "fixture" should be applied to the devices that hold, support, and locate the workpiece in relation to the cutting tool. They are usually fixed to the machine. In this section, we will discuss the types and uses of jigs and fixtures, as well as the various methods used to fabricate them.

605. Cite the closed or box drill jig's main characteristics and associate each type of jig with the characteristics of that type.

Jigs. The various types of jigs—especially drill jigs—are our concern here. As we have stated earlier, jigs hold, support, and locate the part to be machined in addition to guiding the cutting tool. Jigs can be divided into two general classes: (1) drill jigs and (2) boring jigs. Because of limited equipment, drill jigs are used more by the Air Force machinist than are boring jigs. For this reason, we will limit our discussion to drill jigs. This takes in the (1) template, (2) plate, (3) channel, (4) angle plate, (5) closed box, (6) indexing or rotary, and (7) combination jigs.

Template. The template jig is used for limited production. It is employed more for accuracy in locating the drill bit than it is for labor- or time-saving. The template jigs, shown in figure 1-6, were designed for drilling out three pins that hold a grease seal. These pins could not be drilled out accurately by any other method.

Plate. The plate jig, shown in figure 1-7, gets its name from the fact that the largest part of it is a plate. The other essential parts are locating pins, drill bushings, and a clamping device. A jig of this kind can be used for drilling holes in a flat workpiece.

Channel. The channel jig, shown in figure 1-8, is made for parts with a simple symmetrical shape. The channel jig is hollow and holds the part inside its walls

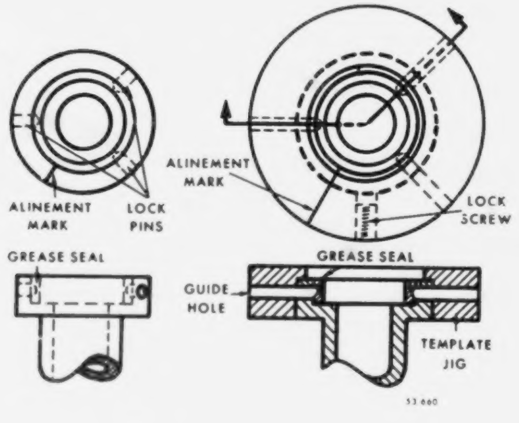


Figure 1-6. Template jig.

by means of a locking device, such as the lockscrew illustrated.

Angle plate. The angle plate jig, shown in figure 1-9, is especially adaptable for locating and drilling holes for setscrews on such parts as collars, pulleys, and gears. This type of jig can be constructed easily, so that it can locate and guide a drill or cutting tool in an angular plane other than vertical.

Closed or box. Closed or box jigs are designed to completely or partially inclose the part to be machined. They are used on parts in which holes must be drilled from several directions. To firmly support the jig, it must be equipped with four feet or legs. These supports are located on the opposite side of the box from the drilling surfaces. Closed or box jigs sometimes have a leaf or cover, which swings back to allow loading and unloading of the parts. Devices for accurately locating and clamping the workpiece are usually permanently attached to the jig body.

Indexing or rotary. Indexing or rotary jigs are used for drilling holes that must be located at angles to each other. This type of jig may be partially or fully inclosed. By means of locators and clamps, the work is mounted on a swiveling or rotating drum (trunnion), so that the workpiece can be indexed to the proper location in line with a stationary drill bushing. This type of jig may be simple or complex, depending upon the accuracy required and the number of parts to be manufactured. It can also be designed to hold several identical parts and be manually or automatically operated.

A special type of indexing jig is often built for large parts that are too heavy to handle. These are generally box type jigs, which are mounted on bearings or trunnions. Mounting these jigs on bearings makes it quite easy to move them into position for the drilling operations.

Combination. Combination jigs are used when more than one operation is to be performed on the same hole, such as drilling, reaming, boring, tapping, countersinking, and counterboring. The use of combination jigs is possible because of their slip renewable bushings. After the part is placed in the jig and properly located and clamped, the hole is drilled, and the bushing is removed and replaced by a different bushing for subsequent operations.

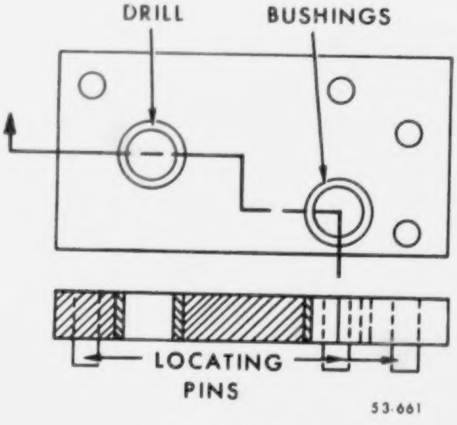


Figure 1-7. Plate jig.

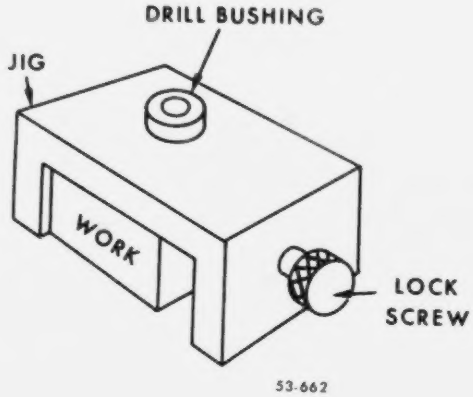


Figure 1-8. Channel jig.

Exercises (605):

1. Give the main characteristics of a closed or box drill jig.

2. Match each of the jig uses shown in column B with the jig type, found in column A, so used by writing the number beside each use in the space provided before its associated letter-coded jig type. Each item in column B may be used once or not at all.

Column A

_____ a. Template.
_____ b. Plate.
_____ c. Channel.
_____ d. Angle plate.
_____ e. Closed or box.
_____ f. Indexing or rotary.
_____ g. Combination.

Column B

1. For holding parts with simple symmetrical shapes.
2. For holding parts that must be drilled from more than one direction.
3. For drilling out four parts holding a grease seal.
4. For holding several identical parts at once.
5. For drilling holes that must be located at angles to each other.
6. For locating holes for setscrews on pulleys and gears.
7. For drilling holes in a flat workpiece.
8. For guiding a drill or cutting tool in a diagonal instead of a vertical plane.
9. For accurately locating the drill bit on limited production work.
10. For performing more than one operation on the same hole.

606. Compare the characteristics and applications of the various types of jig bushings and fastening and aligning devices with those bushings and devices and indicate the factor(s) determining the design/shape of such devices.

The various kinds of jig bushings and fastening and aligning devices are important to machinists. That is why they are covered at this point.

Types of Jig Bushings. Jig bushings are made of hardened steel. You must fabricate the bushing as well as the jig. These five main types of jig bushings are our topic here: (1) press fit, (2) fixed renewable, (3) slip renewable, (4) screw, and (5) special.

Press fit. Press-fit bushings are permanently pressed into position. Used only for limited production, they are put into simple jigs that are employed for just one machining operation, such as drilling. Two types of press-fit bushings exist: (1) plain and (2) shoulder. Plain bushings can be set closer together than can shoulder bushings. It is better to use them when their location in a jig requires a flush surface or when the holes in the jig plate are closely spaced. However, shoulder bushings are better for general use because there is less danger of their becoming dislodged by the cutting tools.

Fixed renewable. A fixed-renewable bushing fits into an outer sleeve, which is pressed into the jig plate. It is kept in place until it is worn out. Then it is replaced without changing the dimensions of the sleeve in the jig plate.

Slip renewable. The slip-renewable bushing also fits a sleeve. It makes possible the drilling of several holes, because it can be moved from hole to hole. Also, bushings of different sizes can be used in the same sleeve to facilitate drilling, reaming, and boring. This type of bushing must be clamped to keep it from rotating with the drill or cutting tool and from rising from the sleeve. Many ways can be used to clamp a bushing in place, as shown in figure 1-10.

Screw. The screw bushing, shown in figure 1-11, performs well for light work with large tolerances. These bushings not only guide the tool but also clamp the work firmly and eliminate the need for other holding devices. A disadvantage of this type of bushing is that, when the thread becomes worn, it is inaccurate. A screw bushing must have a head that can be turned by a wrench. For the several different types of heads, shown in figure 1-12, you use (from left to right) (1) an end wrench, (2) a round-tipped spanner, (3) a square-tipped spanner, (4) a socket or box end, and (5) a special pin wrench, respectively. In each case, the intended use of the bushing determines the type of head you will select.

Special. Special bushings can be designed and made according to the task they must perform. Here your skill and ingenuity are your only guides. If an operation requires a bushing that is not of a normal configuration—for example, when the holes to be drilled are too close together to use three separate bushings—you must design a single bushing to accommodate the three holes.

Fastening and Aligning Devices. For every type of jig or fixture designed and used in any machine shop, there must be some means of clamping the workpiece to either the jig or the fixture. Also, some provision must be made for alignment. The design of clamping devices is limited only by your imagination. Some of the more common clamps are the screw, cam, hook, wedge, toggle, and rack and pinion. You can use one or all of these in one form or another. The function of the jig will guide you in selecting the type to use for clamping. Aligning devices are many and varied. Here again, the size, shape, and operational need governs the type of aligning device you should use.

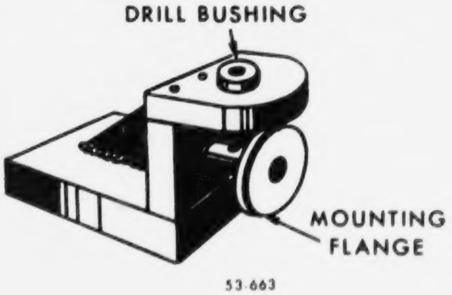


Figure 1-9. Angle plate jig.

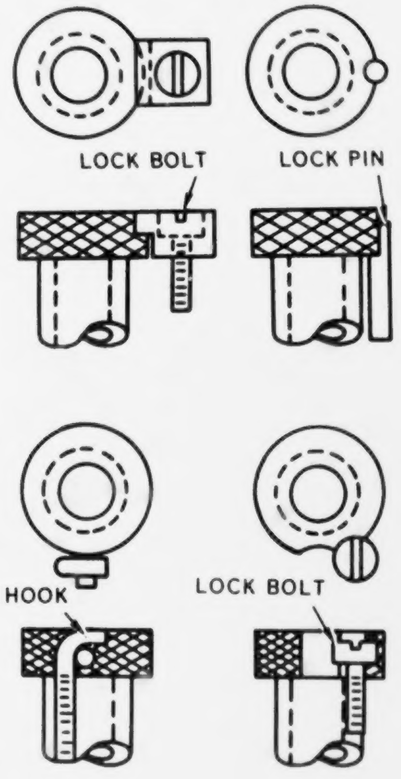


Figure 1-10. Bushing clamps.

Exercises (606):

1. Match each jig bushing characteristic or application shown in column B with its corresponding type of jig bushing, given in column A, by putting each number-coded characteristic or application in the appropriate space beside its associated letter-coded jig bushing. Each type of jig bushing may have one or more than one applicable characteristic or application.

Column A

_____ a. Press fit.
_____ b. Fixed renewable.
_____ c. Slip renewable.
_____ d. Screw.
_____ e. Special.

Column B

1. Fits into an outer sleeve that is pressed into the jig.
2. Is best suited for light work with large tolerances.
3. Is used mainly in simple jigs that are used for only one machining operation.
4. Shape is designed to fit the task they must perform.
5. Is pressed into an outer sleeve.
6. Must have a head that can be turned with a wrench.
7. Are designed either as plain or as shoulder-type bushings.

2. Tell what governs the design or shape of fastenings and aligning devices.

607. Give the features of selected types of milling fixtures and their uses and, given a typical situation, identify the fixture type most suitable for the job.

Numerous kinds of or classes of fixtures exist and are of concern to us here.

Fixtures. Several classes of fixtures which exist can be subdivided into many types. In each case, however, the class of a fixture is determined by the machine on which it is used. A few examples of the machines on which you use fixtures are the milling machine, planer, lathe, boring mill, and turret lathe. You can also design these fixtures to be used on more than one machine. However, we will limit our discussion here to milling fixtures.

As we have said, the type of fixture selected depends upon both the kind of milling operation to be performed and the type of cutter used. Milling fixtures aid in the performance of many milling operations. Among these are (1) form milling, (2) angular milling, (3) T-slot cutting, and (4) straddle milling.

Auxiliary vise jaw. One of the simplest and most widely used fixtures is a set of auxiliary vise jaws. These vise jaws are built to replace standard vise jaws and are used for simple milling operations, if the shape and the size of the workpiece permit. But although they are usually made to fit only one part, an exception is the V-block vise jaw. The governing factors of this special vise jaw are the size of the vise and the depth to which the V-block is cut. The auxiliary jaw usually replaces the stationary jaw in the vise, with the movable jaw only holding the part in place. As a usual rule, auxiliary vise jaws are made of

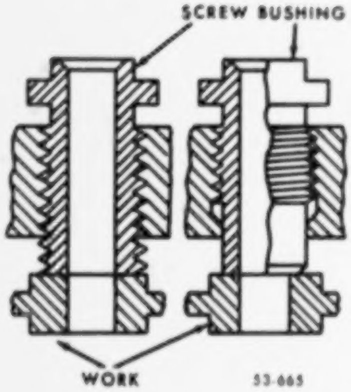


Figure 1-11. Screw bushings.

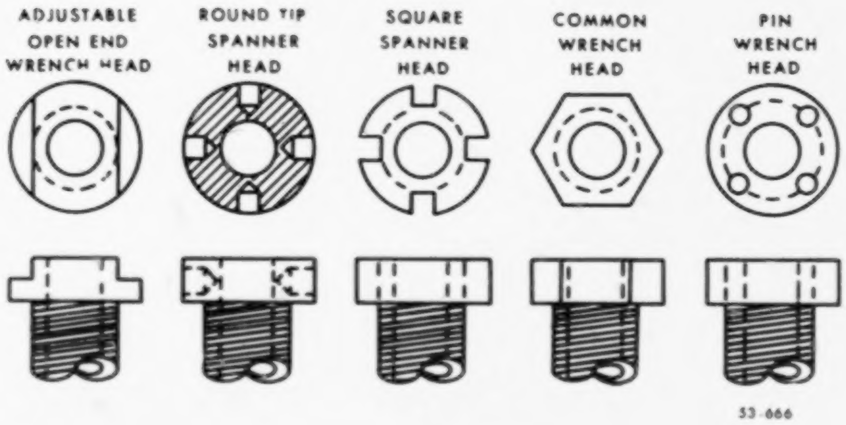


Figure 1-12. Screw bushing heads.

low carbon steel and are case-hardened. For short runs or low production jobs, however, they need not be case-hardened.

Angle plate fixtures. Angle plate type fixtures are designed to hold a part for slotting or face milling. This kind of fixture is built on a base plate, with another plate located at an angle to the base. The angle plate milling fixture is made like an angle plate. It can be made at any desired angle. The workpiece is located and securely clamped on the face of the angle plate.

Multiple and duplex fixtures. Fixtures holding two or more similar parts are termed "gang" or "multiple fixtures." With a little change, however, they can be converted to continuous milling fixtures, if provisions are made for clamping each part separately. Duplex fixtures are designed so that, as one part is completed, it can be removed while another part is being machined. Also, two similar fixtures can be mounted at opposite ends of the indexing base. This enables you to load or unload one fixture, while the part in the other fixture is being machined. After machining has been completed on the workpiece in one fixture, the fixture on the other end is swung into position for the machining operation.

In some cases, you may need a fixture with which you can perform more than one operation without removing the part. This is done in machining castings that must have subsequent operations performed on them. In order to maintain accuracy, the parts must remain in the fixture, and the fixture must be moved to the next machine. Some castings are very difficult to reset in another fixture or even to reset in the same fixture, because of their rough and uneven surfaces.

Exercises (607):

1. Give the features of the auxiliary vise jaw type of milling fixtures.

2. *Situation:* You must mill a surface at a 29° angle on three like parts which are irregularly shaped. Identify the type of fixture best suited for this job.

3. Indicate the way in which duplex fixtures are used.

608. Differentiate among the features and uses of the most common types of body construction used in fabricating jigs and fixtures, specify the elementary movements needing restriction to fully confine an object, and clarify the 3-2-1 principle of locating work in them.

At this point we will discuss the fabricating of jigs and fixtures and the locating of points.

Fabrication of Jigs and Fixtures. There are several methods of fabricating jig and fixture bodies. We will discuss the three most common types of body construction that are used by tool makers: buildup, welded, and cast or one piece.

Built-up type. The built-up type, usually fabricated by fastening together steel plates with screws and dowel pins, is a convenient and economical method. Dowel pins must be used to align the parts and to keep them in alignment. The screws simply hold the parts of the tool body together. Remember, however, that this type of tool body lacks the rigidity of the cast and welded body types. Its accuracy can be distorted by careless handling and loosening of the screws that hold the parts together.

Welded type. The welded type of body construction is an outgrowth of the built-up type. The difference between them is that the built-up type is put together with screws and dowel pins; whereas the welded type is welded together. The welded bodies are often preferred because of their greater strength and rigidity. Another advantage of the welded body type is that it is easily altered, permitting its adaptation to a part other than the one for which it was designed. Note, however, that the surfaces of welded type tool bodies, which must serve as bearing surfaces, base lines, or surfaces on which accessories are mounted, must be machined after welding. This minimizes distortion and other imperfections caused by the welding, normalizing, and sand-blasting processes.

Cast or one-piece type. The cast or one-piece type of tool body is often required in the construction of special tools. It can be molded into any necessary size and shape and can be designed to require a minimum amount of machining. Cast bodies can be easily lightened by coring out material without reducing their strength and rigidity. You will be more likely to work with the one-piece body. The only difference that distinguishes the cast type from the one-piece body type is that the latter is machined from a solid piece of stock. It has the same strength and rigidity as the cast type. Yet, if possible, avoid the use of the one-piece type, because of the cost of manufacturing it.

Locating Points. In the manufacture of a large number of parts, tools and machines are arranged to carry out definite routines. Since aircraft construction requires accuracy, all of the parts in an operation must be presented to the tools in as nearly the same position as possible. Each part must be located on enough surfaces to give it a definite place in which it can be held securely. Common surfaces have the form of planes, cylinders, and cones. Some parts have special surfaces and are most complicated to locate. Many means of locating have been devised to cope with all types of surfaces, but the key to all of them is in the principles of locating. What does this involve?

To begin with, note that confinement alone does not insure location. For instance, a part may be held in a vise securely and still not be located. A free body moves in any direction, but restriction of movement in three axial directions prevents motion in any direction. A free body also rotates in any direction, but you can bring a body to any desired position by revolving it about its three axes, as shown in figure 1-13. Thus, the three linear movements and the three rotations are the six elementary movements that must be restricted in order to confine an object completely.

The locating points are used to position the part. They should not, however, be confused with clamps. Clamps are, instead, the devices that hold the part firmly against the locating points, which we will designate as "rest buttons."

The 3-2-1 principle of location is usually adopted in building a jig or fixture. What does this principle mean? Well, first, *three locators* on the base keep the part from rocking in any direction. Next, *two contact points* (rest buttons) are found on the vertical member, beside one of the long sides of the part, as shown in figure 1-14. They keep the part from rotating and, also, prevent linear movement in one direction. Finally, *one rest button* is placed on the vertical member, next to an end of the part, to complete the location of the part. Together, these six locators, with the help of the clamps, hold a part rigidly in position. Note here that it is poor practice to put locators in any places other than on the horizontal and vertical planes. Thus, as figure 1-15 illustrates, an error is increased when a rest button contacts the slanting side of the part. The locator also has a tendency to lift the part when the part is clamped, and a wedging action takes place between the locator and the slanting edge of the part. In any event, because of its name, the "3-2-1 principle" is easy to remember when you need it during the construction of jigs, fixtures, and dies.

Exercises (608):

1. Specify why the welded body type of construction is usually preferred over the built-up type of body construction.

2. Differentiate between the cast and the one-piece type of body construction.

3. Tell why the one-piece type of body construction is undesirable when another type of construction can be used.

4. Identify the six elementary movements that must be restricted to completely confine an object.

5. Clarify the 3-2-1 principle of location.

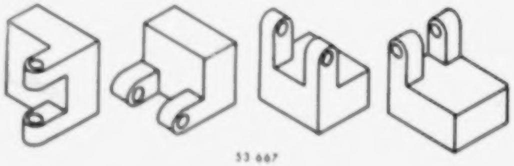


Figure 1-13. Revolving an object to the desired position.

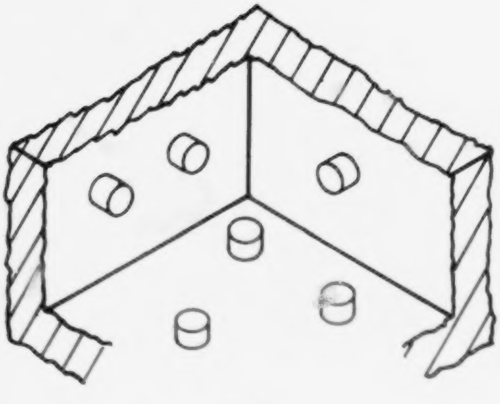


Figure 1-14. Location of rest buttons.

609. Clarify how various surface conditions on work can affect the use and positioning of locators and specify the characteristics and uses of selected types of locators.

Our next subject involves surface conditions and types of locators, in that order.

Surface Conditions. Both types of locators and the number of locators needed to position a part depend upon the finish of the locating surfaces on that part. The three kinds of surfaces usually found on parts are these: (1) finished, (2) semifinished, and (3) rough.

Finished surfaces. Finished surfaces have been machined until they are smooth and true. They can be located on flat surfaces, which make full contact. However, if any metal chips from the previously machined parts are left on the location surfaces, the next part can not be located accurately. The use of rest buttons minimizes this problem. More than three locating points on one surface do not improve location, but they may be used to give the needed rigidity to parts with finished surfaces. Still, if more than three rest buttons are used on one surface, the buttons must be ground to the same height to prevent the piece from rocking. The reason, of course, is that if a part were clamped on locators of uneven height, it would be machined in a warped position, producing an untrue machined surface.

Semifinished surfaces. Semifinished surfaces have been rough-machined but still contain some warpage and a slight amount of roughness. If more than three locators are used on one surface, the additional locators should be adjustable to allow for the variations in the different parts.

Rough surfaces. Rough surfaces are unmachined and have wide variations. To cope with rough surfaces, keep the locating buttons as far apart as possible to minimize the difference in position of the parts that are being machined, as shown in figure 1-16. Also, use the minimum number of locating points necessary to hold the part rigidly.

Types of Locators. The shape of a part determines the type of locator best suited for the job. That is, each type of locator is superior to the others when it is positioning the shape of a part for which it is best adapted. The types of locators and their uses are covered in the following paragraphs, beginning with V-locators.

V-locators. V-locators are the best kind to use for holding cylindrically shaped objects. The reason is that when a cylinder is placed on a V-block, it loses all but two degrees of freedom—it can rotate about its own axis and it can move lengthwise in the V-slot. But if a stop is put at one end of the V-block, the cylinder can no longer move lengthwise. And if the cylinder is clamped to the V-block, the cylinder loses its last degree of freedom, rotation about its axis. A rough, cylindrically shaped object should have a V-locator near each end instead of one V-block to hold it over its entire length. This minimizes rock or spring in the part. V-locators are also used for parts other than cylinders. An example of the V-blocks that are used as centralizers for parts with radial ends is shown in figure 1-17. The placement of a V-locator is important. For drilling through the diameter of rods of different sizes, position the V-block, so that the center of any sized rod is in line with the axis of the drill bushing.

Cylindrical locators. Parts that have had holes drilled in them during a previous machining operation can be located for subsequent machining operations by cylindrical locators placed to fit into the holes. There are also many other uses for cylindrical locators. For instance, the assemblies in a jet engine, such as the compressor and the turbine, are cylindrical in shape and are held by cylindrical locators during machining operations.

Conical locators. In many cases, conical locators are more adaptable than are cylindrical ones. If there is a tolerance for the hole sizes in a part, the cylindrical locator must be smaller than the smallest hole size allowed. The lateral movement of the part with the largest hole diameter within tolerance on this same locator can be excessive. But you can use a conical or tapered plug to overcome the variation of the placement of the part in the fixture. Thus, a common use of conical locators is holding work between centers on a lathe. Another tapered locator is the mandrel, which can be pressed into a centrally located, straight-machined hole of a part, so that the part can be turned

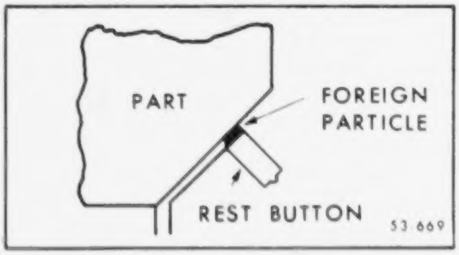


Figure 1-15. Position error.

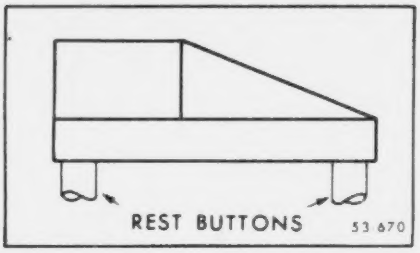


Figure 1-16. Wide separation of rest buttons.

between centers. Another application of the conical locators is illustrated in figure 1-18. A rough blank is located from its hub by an internal cone in the end of a screw bushing.

A part, located by means of a cylindrical plug, often needs to rest against another locator to keep it from rotating during the machining operation. Note how this is shown in figure 1-19. The pin used to prevent the part from revolving should be so placed that its point of contact with the part is as far as possible from the fulcrum point. A part located by two pins is considered as deriving most of its location from the base of the fixture and one pin. The second pin only keeps the part from rotating around the first pin. The second pin is ground into a diamond shape, leaving cylindrical segments on the two ends of the diamond. By being relieved as it is, the diamond pin locator allows for the slight deviation in measurement between the two respective holes. A closeup of the top view of the diamond locator is shown in figure 1-20. The included angle at each end of the diamond is 60°.

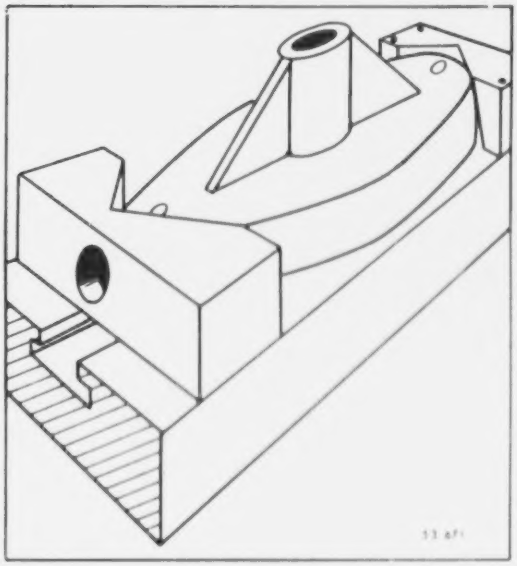


Figure 1-17. V-block centralizers.

The distance across the flats is three-fourths of the diameter of the locator.

Exercises (609):

1. State how a semifinished surface affects the use of locators when more than three are used.

2. Indicate how a rough surface affects the positioning of locators in a jig or fixture.

3. Tell the two degrees of movement that V-blocks fail to restrict on a cylindrical part.

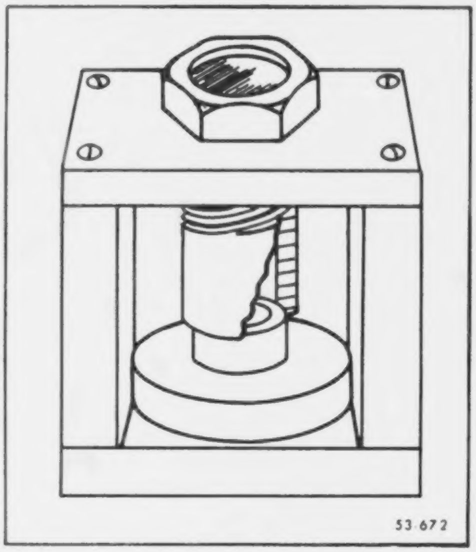


Figure 1-18. Internal cone locator.

4. Give the advantage conical locators have over cylindrical locators.

1-3. Die Design and Fabrication

Both the design and the fabrication of metal cutting and forming dies are very important parts of your job as a machinist. These punches and dies can save you many hours of work. In this section we will discuss the basic press operations and the design and fabrication of punches and dies.

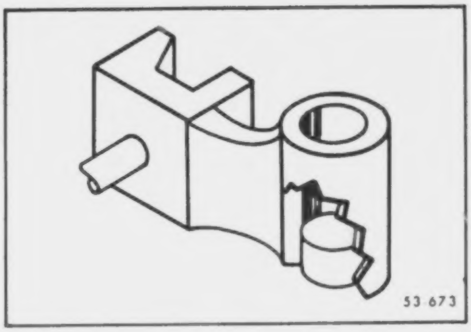


Figure 1-19. Radial locator.

610. Analyze the various types of die operations, giving the features of the various standardized die sets and parts and, provided a typical situation, identify the die set to choose.

We turn now to types of die operations and die sets and parts.

Types of Die Operations. Press tools provide one of the major methods of producing metal parts. Their range and application have become almost unlimited. Many articles that were formerly produced by machining operations have become products of the press department. In earlier years, press work was limited to small items, but now there is apparently no limit to the size and variety of parts that can be made on the press. These vary from small metal eyelets to automobile body parts, such as fenders and similar pieces of large dimensions. Press tools may be divided into groups based on their affect upon the structure of the metal to which they are applied. Accordingly, some tools act upon the metal by means of some form of shearing or cutting action, such as blanking, piercing, or shearing. Some other tools work the metal in the sense that they cause it to flow; forming and drawing tools are typical of this group. Most press-work falls into one of the following types of operations.

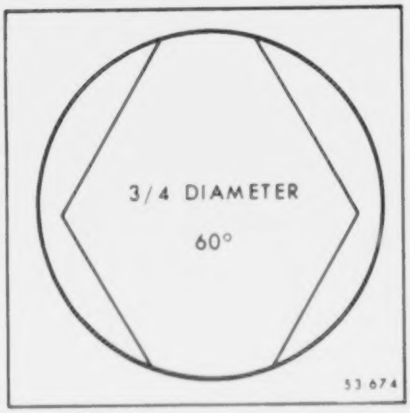


Figure 1-20. Top view of a diamond locator.

Blanking. Blanking is the operation of cutting out a part with a punch and die. The material used is termed the "stock." During the working stroke, the punch goes through the material. After the material is cut, it drops through the die, and the punch returns to its original position. Figure 1-21 illustrates the action of a blanking die. The work is fed by hand or by some type of feed device. Stop pins are usually used to gage the stock, so that maximum stock is used.

Piercing. The piercing operation consists of the punching of holes. It differs from blanking in that the punched out material is the scrap. Both flat-ended and spiral-cutting piercing punches are used. A flat-ended punch is illustrated in figure 1-22. It is often thought that piercing dies principally produce round holes. Instead, they are almost as frequently used for making openings of other shapes, such as square, oblong, irregular, curved, and slotted.

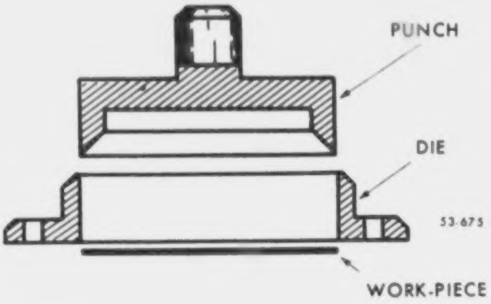


Figure 1-21. Blanking die.

Bending and forming. Bending and forming dies are made in great variety and operate on all classes of work. As the name implies, this operation forms or bends the blanks. A simple form of bending die is illustrated in figure 1-23. The outline of the bend, which is to be imparted to the blank, is formed on the punch and die. Quite frequently, when more intricate forms are required, the work is passed through two sets of dies, one for starting the outline and the other for completing the work.

Drawing. The production of cups, shells, boxes, and similar articles from metal blanks is termed "drawing." In this process, a piece of flat stock, such as brass or steel, is pushed through a round die by a dull-ended punch that cannot cut through the stock. An example is shown in figure 1-24. The shell that is pushed through the die is removed from the punch on the upward stroke by catching on the stripping edge.

Crimping. By "crimping" we mean pinching or squeezing the sides of a shell in order to hold an object. An example is the crimping of a cartridge shell to hold the bullet in place.

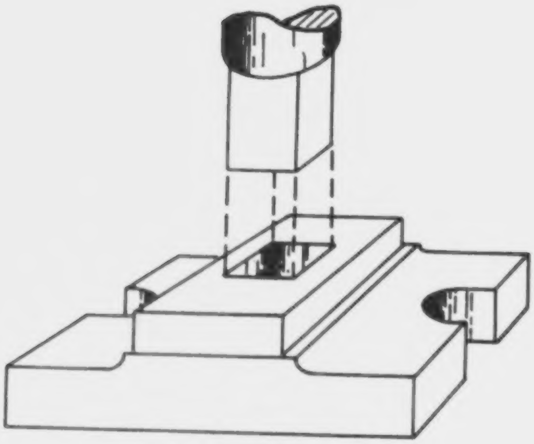


Figure 1-22. Piercing die.

Coining. As is implied by the name, "coining" is forcing metal into dies for the purpose of making letters and similar markings in relief.

Deep drawing. Designing die sets for deep drawing is a very complicated process and requires considerable skill and experience. We will discuss only the general principles. Deep drawing is possible only by dividing the work into several stages or draws. Between each draw, the workpiece is annealed by heat, because cold-working the metal makes it hard and brittle. It is not possible to make long deep draws in one single stage, because the workpiece, even if made of the softest material, would split and crack.

Deep drawing is often accompanied by an operation termed "ironing." Ironing is reducing the wall thickness of a shell by forcing it through a tight die. The walls of the shell are both lengthened and made thinner, but the thickness of the shell bottom is not changed during the ironing operation. The space between the punch and die must be less than the thickness of the stock. Dies and other working parts used for ironing operations must be hardened, ground, and highly polished.

Die Sets and Parts. Standardized die sets are used very extensively in many different sizes and styles. When a tool designer has a product for which he must design a die, he studies the job carefully and selects a suitable die set upon which he can mount his punches and dies. Standard die sets have two basic parts: the punch holder and the die shoe, as shown in figure 1-25. Figure 1-26 shows the other parts of a standard die set. These are the shank, by which the punch holder is fastened to the press; the guide pins, which insure that the punch is in accurate alignment with the die, and the bushings. The guide pins and bushings are made of hardened steel.

Other standard parts can be purchased, such as springs, dowels, and stripper bolts. Five types of standard die sets are available, but the one most frequently used is the *back-pin* set, shown in figures 1-25 and 1-26. In this type of die set, the pins are located at the back of the set, leaving clear space for hand-feeding the blanks. It also permits a good view of the moving parts, free from obstructing pins and bushings. The *center-pin* type die set is used when the load is heavy and is fed from the front. The guide pins are in alignment with the load along the transverse centerline of the set. This leaves the front clear but prevents end-feeding either by hand or automatically.

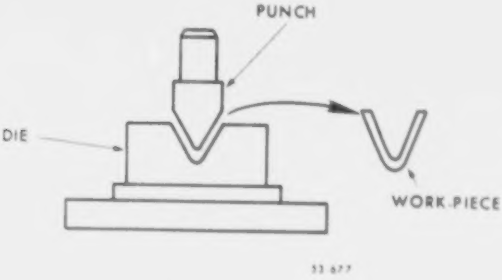


Figure 1-23. Bending die.

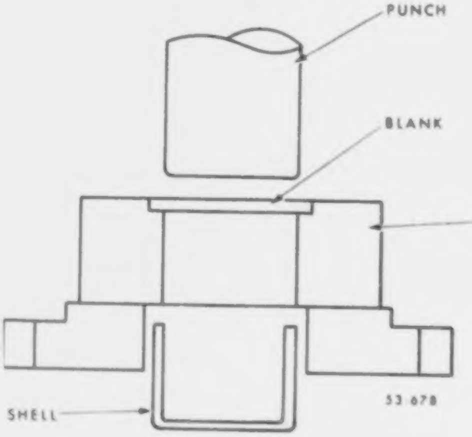


Figure 1-24. Drawing die.

The *diagonal-pin* type set is usually used if very heavy loading is required. In this arrangement, which also uses only two pins, one guide pin is placed at the front of the set to avoid the overhand of the back-pin type. The load is in alignment with the pins along a diagonal line and leaves the end clear for feeding. The left pin is generally in front, but if the designer wishes to feed from the left, he can put the right pin forward. The final decision is based on the arrangement that gives the best view of the stop pins and is more adaptable to standard guards.

Round-die sets are made especially for coining and shaving operations. The guide pins are usually found along the back, but they can be at the center, if needed there. The punch holders and die shoes are usually round or oval-shaped.

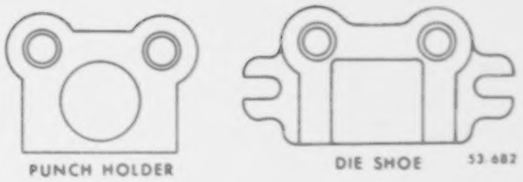


Figure 1-25. Die parts.

The *four-pin* type die set is used for roll-fed operations, especially for progressive dies with several stations. This die set provides maximum rigidity and accuracy of alignment, because of a guide pin at each corner of the die. The front pins are inconvenient for hand operations and can even be dangerous unless excellent guards are provided.

A relatively new development to provide more accurate alignment of punches with their dies is the *anti-friction die* set. Preloaded ball bearings between the leader pins and bushings reduce lateral motion to an absolute minimum. The motion is linear; so standard radial ball bearings cannot be used. The linear bearings that are used have seven or more rows of relatively small ball bearings mounted in a retainer. The guide pin acts as an inner race, and the bushing of the die acts as the outer race. This type of die set operates very freely. Small sets can be opened and closed very easily by hand. Lubrication problems are reduced, and the use of these bearings increases the life of the set.

Exercises (610):

1. Distinguish between the blanking and piercing operations.

2. State what happens to the metal blank in a drawing operation.

3. Give the purpose of *coining*.

4. Clarify the *ironing* process as used in a deep drawing operation.

5. Identify the two basic parts of a standard die set.

6. Detail the most commonly used type of standard die set.

7. State what, on the diagonal-pin set, determines whether the front pin will be on the right or the left side.

8. *Situation:* you must design a progressive punch and die for some heavy work that will require maximum rigidity in the die set. Tell the type of die set you should choose.

611. Detail the principal characteristics and operating procedures of the various types of dies.

What types of dies exist, and how are they designed? These questions are answered here.

Types of Dies and Their Design. Three general types of dies exist, having many possible variations. These three general types are: (1) inverted, (2) progressive, and (3) compound dies. We will discuss these in the following paragraphs.

Inverted. As its name implies, in an "inverted die," the punch is mounted in the die shoe; and the die is carried in the punch holder. This arrangement is advantageous in blanking thin stock. The inverted die lessens the possibility of bending the blank. Figure 1-27 illustrates the action and arrangement of an inverted die set. In the standard die set, the blanks may become crowded in the die cavity and cause a jam. This is especially true if the press is working at maximum capacity. Instead of forcing the blank through the die, the inverted die is so arranged that the blank is removed by a knockout pin as soon as it is cut. A very important advantage of the inverted die is that the stripper and ejector keep cutting edges free of chips, and the edges need less regrinding. Note, however, that inverted dies are relatively high at first cost.

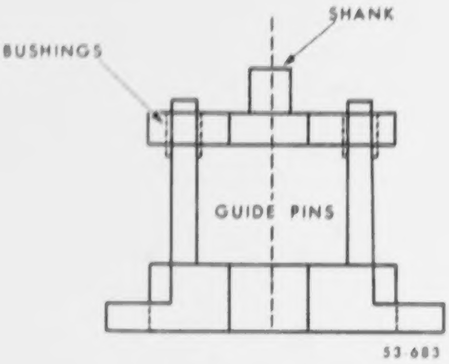


Figure 1-26. Assembled standard die parts.

Progressive. What are termed "progressive die sets" perform two or more operations at different stages each time the ram descends. Figure 1-28 illustrates a simple progressive die. Refer to this figure, as we explain this type of die. The stock is fed progressively into the die set, the two operations on the stock following each other. At step one, a round hole is pierced, and the slug becomes scrap. The stock is then advanced to step two, either by hand or by a mechanical feeding device. On the second downward stroke, the workpiece is blanked out, and another hole is pierced in what will be the second blank. The pilot on the blanking punch enters the pierced hole to insure exact alignment of the stock before it is blanked. The pilot is detachable, so that it can be removed if it is necessary to sharpen the punch. Progressive dies can be made, and are made, with many stations. In some progressive dies, the blanks are cut first. Then spring plates return the blank to the strip. The strip then carries the blank to the following strips, where the blank is pierced and formed.

The main advantage of progressive dies lies in their speed of operation, particularly in setups where automatic feeds and magazine stacking of workpieces are possible. Progressive dies are used extensively in industry for this reason. Certain disadvantages must be considered. One of them is that the workpiece is not supported as it is pushed through the die; consequently, the blank may have a dished effect. If this happens, the blank needs an additional flattening operation at extra cost. In most progressive die operations, the positioning of the strip by action of the pilot is satisfactory. But when thin stock of soft material is used, it may bend or tear around the pilot holes. This is especially true in the die sets that have many stations, where the friction and inertia of the stock are considerable.

When you are arranging the sequence of operations for progressive dies, place piercing operations first. You can use any required holes as pilot holes, but if they are not satisfactory, you can place special pilot holes in the scrap part of the strip. If it is necessary for you to punch irregularly shaped parts, it is advisable for you to punch the part at several stations. Irregularly shaped punches with frail projections are hard to machine and may break easily after a few runs. For this reason make operations that bend and form the last step. Also, take care to avoid placing pierced holes close to a bend.

Compound. That known as a "compound die" is one that performs several operations during one stroke of the press at one station. To do this, both the upper and lower members of the die set carry the punch and die elements, together with the necessary strippers or ejectors. Figure 1-29 illustrates a simple compound die. This die blanks and draws a shell. Determine its action from figure 1-29.

The compound die action is such that its product is very accurate, and a die that is made correctly will perform accurately throughout its working life. Compound dies are usually more expensive to construct than the plain die of two-stage design, which is the simplest of the progressive types of press tools. However, on long runs, the initial high first cost is justified. Also, on certain classes of work, the compound die eliminates the necessity for shaving operations. The compound die was originally adapted for small circular blanks of small tooth wheels, special washer-shaped parts, pierced instrument elements, and other similar parts. It was later enlarged for almost every kind of work where its application is advantageous economically or mechanically.

The usual arrangement of a compound punch and die involves locating the blanking die in the punch holder or upper portion of the die set. The piercing punches are then fitted in the blanking die, and the piercing dies are drilled or formed in the blanking punch in the die shoe or lower portion of the die set. There are a number of reasons for this practice, such as that when there is no knockout for the upper die or—owing to the size of the work—when it is not feasible to introduce a knockout into the upper die shank. With the blanking punch fitted below to the die shoe, the piercings or slugs pass down through the die shoe as with a plain piercing die.

Compound dies operate more slowly than progressive dies, but they have advantages for certain jobs, especially where close tolerances must be held. Some of these advantages are listed below:

- The action of the pressure pad assures the flatness of the blank.
- A pierced hole in the blank can be held to close tolerance with the edge. This is important when the hole must be concentric with the edges of a part.
- Larger parts can be blanked in a smaller press if compound rather than progressive dies are used.
- Long strips of material are needed with progressive dies.

Sometimes scrap blanks are available. These can be hand-fed to a compound die when the savings in material offset the cost of the labor.

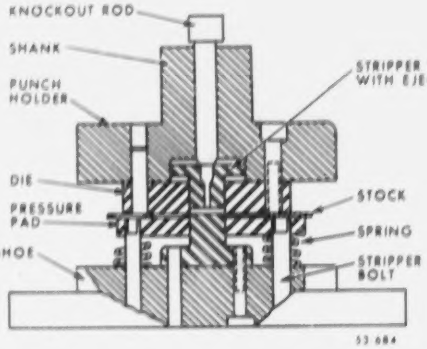


Figure 1-27. Inverted die.

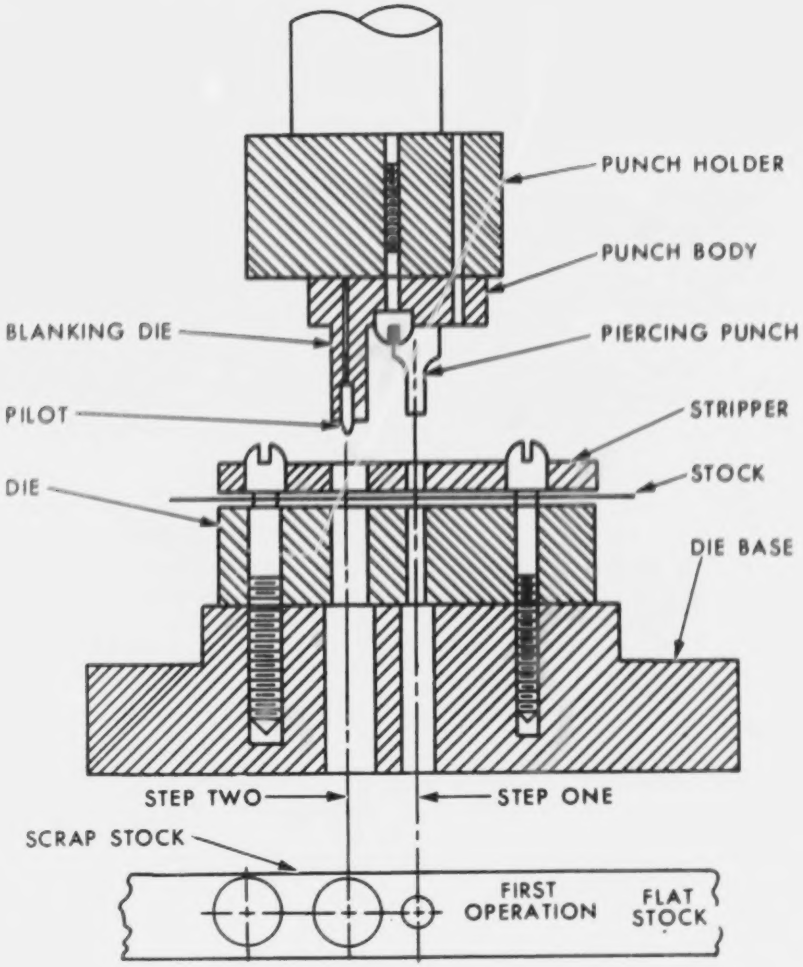

PUNCH HOLDER
PUNCH BODY
BLANKING DIE
PIERCING PUNCH
PILOT
STRIPPER
STOCK
DIE
DIE BASE
STEP TWO
STEP ONE
SCRAP STOCK
FIRST OPERATION
FLAT STOCK

Figure 1-28. Progressive die.

Exercises (611):

1. Give the advantages obtainable by using an inverted die instead of a standard die.

2. Provide the recommended sequence of operations for progressive dies.

3. State the usual arrangement of the piercing and blanking dies and punches in a compound die.

4. Tell how a compound die can be used to obtain a savings in material cost over a progressive die.

612. Clarify the factors to consider when determining the location of blanks in the stock, the importance of the grain in metal-to-die operations, and the mechanisms for locating the stock in the die and, given a hypothetical situation, state whether the procedure used is economical.

You need to know about the location of blanks in stock and stock in dies—our subjects at this time.

Location of Blanks in Stock. The die designer must consider the spacing of blanks on the stock. These two factors must be considered: the best location of blanks to save material and the best location to secure good bending where bending is needed. Both of these matters require good judgment. In fact, it is often wise to cut a few pieces of paper to the required outline of the punching. Then, by arranging them in different ways, you can determine the most economical pattern. Figure 1-30 illustrates the right way to punch stock.

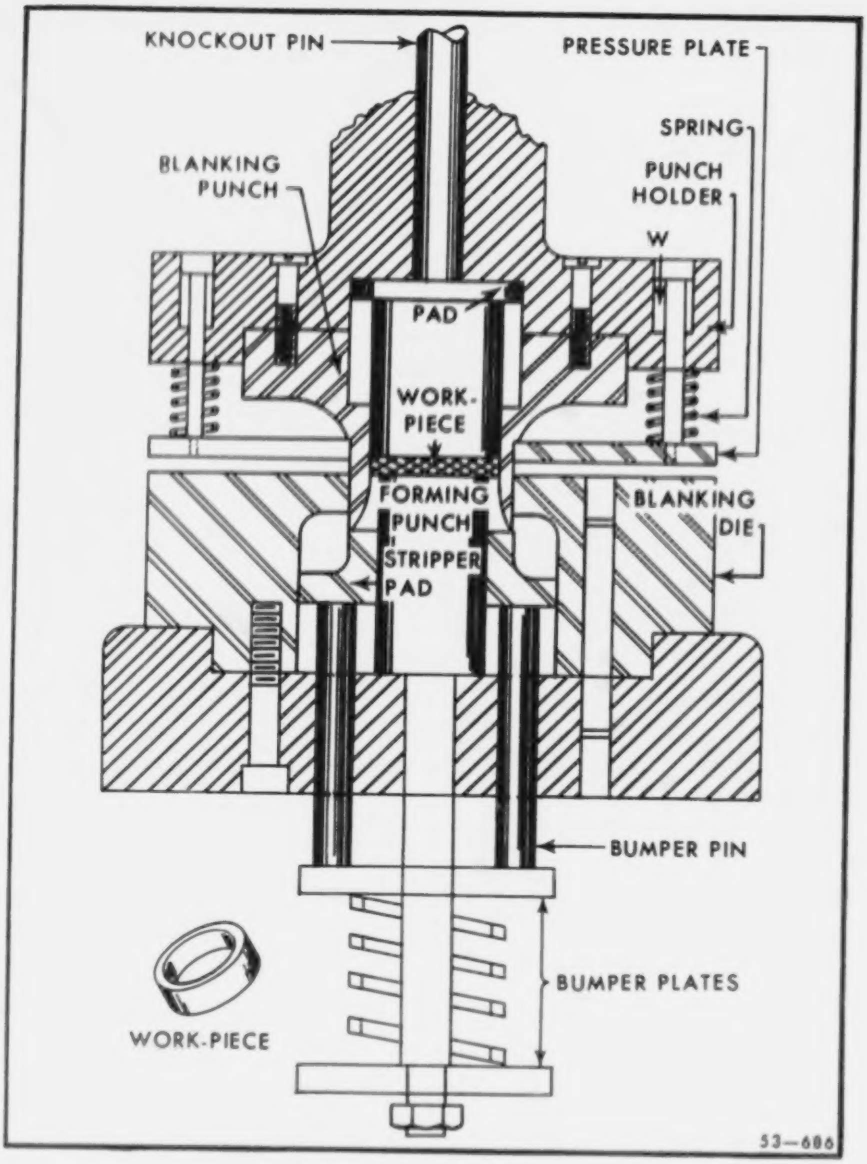

KNOCKOUT PIN
PRESSURE PLATE
SPRING
BLANKING PUNCH
PUNCH HOLDER
W
PAD
WORK-PIECE
FORMING PUNCH
BLANKING DIE
STRIPPER PAD
BUMPER PIN
BUMPER PLATES
WORK-PIECE
53—686

Figure 1-29. Compound die.

The gage pin is so located that there is sufficient stock left between each pair of holes, after the strip passes entirely through the press, to allow it to be reversed and passed through once more. This punches out most of the metal that remains between holes after the first punching. By arranging the operations to take place in this way, you can get a great many more punchings from the same amount of material. However, in choosing this method, you must weigh the extra labor cost against the cost of material saved.

Economical stock size selection. Many times you can save by selecting wire of the proper width of stock. In figure 1-31, you can see that, by using stock wide enough to punch staggered holes, less material is needed for a given number of punchings than you need when using a narrower strip. You can see that the wide stock may not be twice as wide as the narrow stock, but it gives nearly twice the number of parts.

Relation of grain to bending. When you must consider bending blanks after they have been produced,

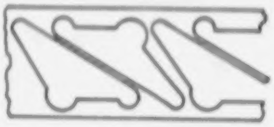


Figure 1-30. Location of blanks.

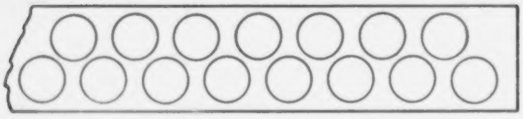


Figure 1-31. Method of locating blanks in stock.

you must understand also that strip steel, like wood, has a definite grain. The grain of sheet metal always runs in the direction of the length of the sheet. Bends should be made across, or at right angles to the grain, and not parallel to it. The figure 3-21 illustrates a part whose shape lends itself to an economical layout at a 45° angle to the grain of the metal. This brings the bend, as illustrated by the dotted line, at 45° to the grain. This angle seldom causes trouble unless a very sharp bend is made or a poor grade of material is used. Bends should not be laid out at less than 45° to the grain. The nearer they come to being directly across the grain, the less trouble will be experienced later from breaking in the formed part.

Location of Stock in Dies. When stock is fed into a press, some method must be used to locate the stock in the proper place. The simplest method is the use of a stop pin, but it has the disadvantage of requiring an operator with considerable skill. Trip dogs are frequently used to determine the amount of the material that should move forward. Figure 1-33 illustrates a typical trip dog arrangement. As the stock is fed forward, the pawl rises on the ratchet principle; then the stock is pulled back, and the pawl drops and locates the stock against the vertical surface of the pawl. Automatic stock stops are used extensively. They are controlled by the action of the punch as it descends or rises. There are many applications of automatic stops designed for specific jobs. If the workpiece has the same width as the stock and the feed is from one side without having a skeleton of scrap material pass out the other side, a shoulder stop is the most effective type. This stop is used on progressive dies where the last operation is a cutoff or trimming one. Figure 1-34 illustrates one of several shoulder stops. Note the indicated use.

Exercises (612):

1. List the two factors to consider concerning the location of blanks in the stock.

2. *Situation:* You find that you can get more blanks from a strip of stock by passing it through the die and then reversing it and passing it through again. Tell what you must consider to determine whether or not this process is economically practical.

3. Specify how more blanks can sometimes be obtained by increasing the width of the stock rather than by using two smaller strips.

4. Clarify the importance of grain in metal to die operations.

5. Detail the action of a trip dog in locating stock in a die.

613. Give the purpose and types of strippers and pressure pads and analyze the design of each.

A machinist works with strippers and pressure pads, our topics in this segment of this volume.

Strippers and Pressure Pads. What *are* the functions of strippers and pressure pads? Well, strippers are used to remove the stock from the punch after a blanking or piercing operation. A channel-type stripper is often used. An example is shown in figure 1-35. In fact, a pressure pad is used frequently as a stripper, thus serving a dual purpose. The pressure pad is mounted on the punch holder and is held down by stiff springs. As the punch ram descends, the pressure pad holds the work in place while the punch passes into the die. On the upstroke, the pressure pad is held down momentarily, acting as a stripper. This action wipes the stock from the punch. Figure 1-35 illustrates this action. In simple forming operations, pressure pads are not necessary for stripper purposes. Still, they are used extensively to prevent edgewise movement of the blank after it has been moved from the locating rest by preliminary bending movements. While a blank is being bent or formed, it has a tendency to move sideways, because strip steel has a tendency to resist bending more in certain areas than in others.

Stripper design. Simplicity of design reduces cost. With this in mind, the designed must consider simple channel strippers first. You can build these up with a rectangular plate mounted on a single strip to form a backstop or guide. If the stock must be guided to close

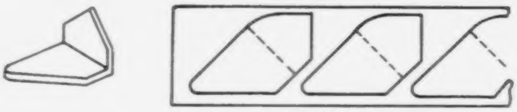


Figure 1-32. Blanks that are to be bent.

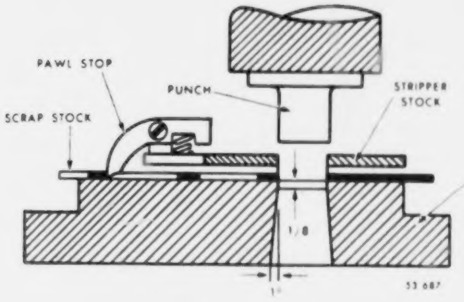


Figure 1-33. Shoulder stop.

tolerances, place a second strip below the original stripper to provide a groove through which the stock is passed. The width of this groove should be at least 0.005 inch larger than the width of the stock, and the height of the groove should be 1½ times the thickness of the stock. Strippers for large die sets can be made of one-piece construction, and the groove can be machined out, as shown in figure 1-35. All strippers must be aligned with dowels to insure accurate alignment on the die holder.

Commercial companies now market special shoulder bolts for pressure pads. You can find the dimensions for these bolts in many catalogs and handbooks. Formerly, the heads had screwdriver slots; now almost all of them contain recessed hexagon sockets of the Allen type. These specially made stripper bolts have an advantage over the capscrews in the definite shoulder—one against which the stripper plate can be fastened. This shoulder positions the stripper plate exactly when the die set is new. However, when the punches are ground for resharpening and are thus shortened, the stripper plate will not be flush with the cutting edge of the punch. To adjust this, you must place washers under the head of the bolts, as shown at W in figure 1-29.

Some designers prefer to use capscrews to avoid this lengthy adjustment. The heads of the capscrews are staked to prevent turning. You can retract the stripper plate by turning the capscrews after grinding the face of the punch, but releasing the staked head is difficult. Capscrews are frequently used with spacers made of steel tubing or pipe. The modern development of self-locking nuts has encouraged the use of nut and bolt construction.

Pressure pad design. Pressure pads for dies are spring- or cushion-actuated. Rubber cushions are satisfactory for short runs when and if the deflection is not too great and the possibility of oil splash is small. Select springs with an inside diameter only slightly larger than the stripper bolts, however. Why? Because if the diameter of the spring is too large compared with that of the bolt, the spring may *cock* sideways and break. Accordingly, it may be advisable for you to counterbore holes in both the stripper and the punch plate to prevent this from happening. The number and placement of springs must be determined by the designer. There is no standard for this; good judgment and experience are the determining factors. However, when you are selecting springs, remember that they are subject to many repetitions of stress and are liable to fatigue failure.

As we have mentioned earlier, it is difficult to determine the pressure needed for stripping. Obviously, if the stock around the punch is frail and stretches easily, little pressure is needed to remove the scrap from the punch. If there is a substantial amount of material around the punch or several punches, the stripping pressure can be as much as ten percent of the cutting pressure. You must consider, then, the amount of pressure needed to hold the stock firmly both while it is being cut and, also, when you are choosing or designing springs.

Exercises (613):

1. State the purpose of strippers in a die set.

2. Indicate the purpose of pressure pads in a die set.

3. Identify the simplest types of strippers.

4. Specify the type of stripper bolts most commonly used for dies utilizing pressure pads as strippers, and indicate how they are adjusted as the punch is resharpened.

5. Tell why the inside diameter of the pressure pad spring should be only slightly larger than the bolt that goes through it.

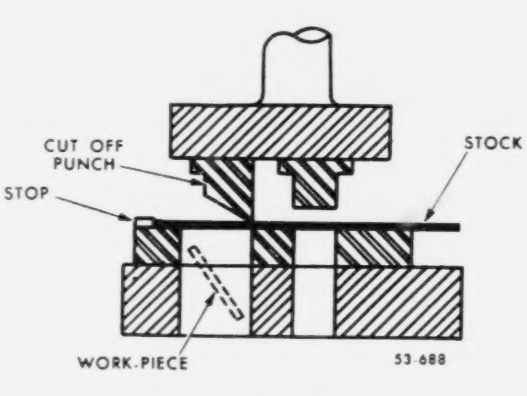


Figure 1-34. Trip stop.

614. Determine the clearance and relief angle requirements for blanking and piercing die operations and define "land of the die" and give its purpose.

To a machinist, clearance and angular relief must be understood. This segment covers these things.

Clearance and Angular Relief. There must be a definite amount of clearance between the punch and the die for blanking or piercing. The amount of clearance is controlled by the thickness and type of material to be blanked. Thus, for thin material with a low tensile strength, such as brass, for example, the clearance is very small. Yet, if too much clearance is applied, the blank will have ragged or burred edges. In any event, heavy stock needs more clearance than thin stock. The reason why it requires greater clearance is to lessen the possibility of breaking the punch or die and to reduce the pressure required to complete the blanking operation. The clearance is designated by two methods, as follows: The first is to designate the space between the punch and the die on *one side only*, or one-half the total difference between the sizes of the punch and the die. This method of designating die clearance is most useful when you are working with parts of nonsymmetrical forms or irregular contours. The second method is to designate the total difference between the sizes of the punch and die. This method works best and is less confusing in connection with symmetrical parts. In all cases, then, be sure to specify the method of designating clearance that you have used. This will help to eliminate confusion and error.

The clearance, which usually allows for brass and soft steel on most dies, on one side, is equal to 5 or 6 percent of the stock's thickness. For some classes of work, one-half of this clearance is preferred. For some piercing operations, a clearance equal to 10 percent of the stock's thickness gives the cleanest fracture. This clearance may be used in such an operation as punching holes in ductile boiler plate.

If blanks are to pass through a die, as seen in figure 1-33, an angular relief is needed to keep the blank from jamming in the passage. The amount of relief ordinarily given a blanking die varies from 1/4° to 2°. However, dies to be used for a relatively small number of blanks are sometimes given a relief of 4° to 5° to facilitate making the die quickly.

There are two methods of applying angular relief to a die. The first method is to extend the angular relief from the bottom of the die to the top surface or to the cutting edge. This method is best suited for thin, soft materials. The second method is to leave a straight section below the cutting edge of the die. This straight section should be about 1/8 inch in width. The second method is best suited for harder materials. The straight section, called the "land of the die," permits many sharpenings of the die without changing the size of the die cavity.

Exercises (614):

1. State how clearance between the punch and the die is designated.

2. Indicate the clearance normally required for mild steel.

3. Tell where angular relief is required for efficient blanking die operation.

4. Specify how much relief is ordinarily provided for efficient blanking die operation.

5. Define "land of the die."

6. Give the purpose of the "land of the die."

615. Indicate important methods of determining the size of the die block and calculations for determining blanking pressure and resolve hypothetical situations involving those methods and calculations.

At this point, die thickness, length and width and blanking pressure should concern you. These are this part of this volume's topics.

Die Thickness, Length and Width. Some general rules for calculating the thickness of small dies exist which you should know. Thus, for blanks with a perimeter of 3 inches or less, use a die block thickness of at least 3/4 inch. Again, for blanks with a perimeter

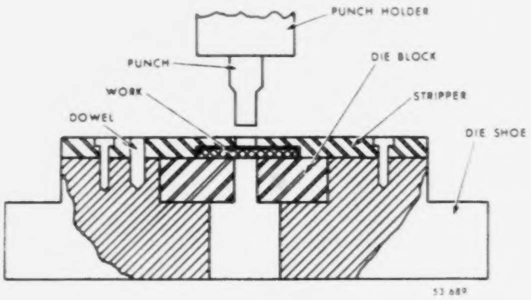


Figure 1-35. Channel-type stripper.

of 3 to 10 inches, use at least a 1-inch die block thickness. Also, for blanks with a perimeter of over 10 inches, use at least a 1¼-inch die block thickness. Consider the situation when you have to manufacture a round die to blank a 7/8-inch disk. Here the perimeter of that part is calculated by multiplying pi (P) times the diameter, which is 3.1416 × .875 = 2.7529. As you can see, then, the perimeter is less than 3 inches; so the die block thickness should be 3/4 inch.

Remember, too, that there should be a margin of 1¼ inches around the die opening. Such a margin needs to be left around the die opening in order to insure that the die does not break during the blanking operation. This margin also provides enough material for capscrews and dowel plans. To calculate the length and width of a rectangular or square die, add 2½ inches to the length and to the width of the part to be manufactured. Thus, for example, calculate the length and width of the die block for a die to blank a rectangle that measures 2.375 inch by 4.875 inch as follows: 2.375 + 2.500 = 4.875 inch width, and 4.875 + 2.500 = 7.375 inch length.

Blanking Pressure. Blanking pressure depends upon the material and the area to be sheared, together with the percent of penetration and the amount of shear on the punch. For round holes, the pressure required equals the circumference of the holes times the thickness of the stock times the shearing strength. The formula is this:

$BP = L \times T \times S$
BP = blanking pressure
L = length of cut in inches
T = thickness of material
S = shear strength of material in psi (pounds per square inch)

To allow some excess pressure, the tensile strength can be substituted for the shearing strength. The tensile strength of common materials is roughly assumed to be as follows: mild steel, 60,000 pounds per square inch; wrought iron, 50,000 pounds; bronze, 40,000 pounds; copper, 30,000 pounds; aluminum, 20,000 pounds; zinc, 10,000 pounds; and tin and lead, 5,000 pounds.

You can reduce the amount of blanking pressure needed to cut a workpiece by as much as 50 percent by placing suitable shear on the punch. Figure 1-36 shows an example of shear applied to a punch. When a shear is placed on a die member, the amount of pressure required to perform the operation is reduced. This result not only reduces the size of the pressure needed but also adds to the life of the punch. If the blank is the workpiece, the shear should be on the die and the punch should be flat, because the shear angle has a tendency to distort the metal. If the blank is scrap and the strip must be flat, the shear should be on the punch. Shear should be applied to the die member that contacts the scrap. The amount of shear added to the punch or die should be equal to a taper, across the face of the punch or die, of 1½ times the thickness of the stock to be blanked. It may, however, be preferable for you to use a double angle starting at the center of the punch or die. Why? Because this double angle helps maintain symmetry and prevents the setup of lateral forces.

Exercises (615):

1. *Situation:* You must make a die for blanking thin stock. The blank measures 0.825 inch square. State how thick the die block should be.

2. Tell how you can determine the width and length of a die for blanking rectangular pieces.

3. *Situation:* You must punch out some 4-inch diameter disks of cast iron which is 0.125 inch thick. Give the blanking pressure which should be used to allow some excess here.

4. *Situation:* You know that the blank is the scrap. Identify the die member to which you should apply a shear angle.

616. Given a typical situation, specify the method for providing the proper clearance on a punch and die set and cite the techniques for contour sawing dies.

A specialist like you works regularly with clearance problems and the contour sawing of dies. This BOF segment discusses these subjects.

Clearance. The application of clearance to the die block of punch is a most important step in the fabrication of dies. Why? Because if clearance is not properly calculated and applied to the proper die members,

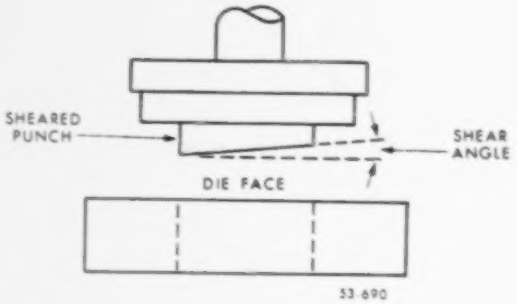


Figure 1-36. Shear applied to punch.

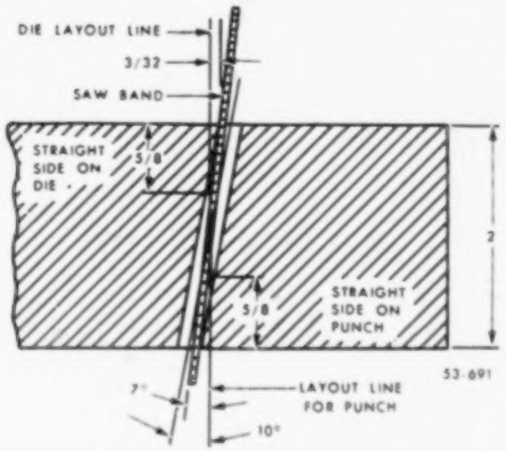


Figure 1-37. Contour sawing of dies.

the parts produced will most likely not meet blueprint specifications. Now the die cavity controls the size of the blank, whereas the punch controls the size of the hole. Using this simple rule, you must decide to which die member the clearance should be applied. Thus, if the die block is the member that receives the clearance, the amount of clearance calculated must be *added* to the size of the die opening. In contrast, if the punch receives the clearance, the amount of clearance calculated is *subtracted* from the size of the punch.

Contour Sawing of Dies. Internal contour sawing is well-suited to producing blanking dies and other straight-through die openings. It is the only process that permits both the die and punch to be machined from the same piece of steel. This procedure, shown in figure 1-37, is not complicated, because every work step and related dimension is based on the thickness of the die block, as indicated in figure 1-38. Three operations are involved:

1. The starting hole is drilled at an angle that varies with the thickness of the material. It is started inside the die layout line and emerges from the die block on the opposite side of the layout line.
2. With the table tilted at an angle slightly less than that of the starting hole, the slug is sawed out of the die block. The path of the saw on the surface is entirely inside the layout line and the proper cutting angle at the bottom of the slug allows for excess material outside the die layout line.
3. With the slug or *punch* removed from the die, the die is band-filed to the layout outline, and the slug is band-filed to fit the die. This filing operation removes all traces of the starting hole on the finished surfaces of both the punch and the die.

Exercises (616):

Use the situation which follows in answering exercises 1 and 2. **You must apply clearance to the die for the blanking of 2-inch disks.**

1. State the die member that should receive the clearance.

2. Indicate how this die member (item 1) should be applied, i.e., added or subtracted.

3. Tell why, when you are contour sawing a punch and die from the same piece of stock, the starting hole is drilled at a different angle than the saw cut.

4. Clarify the relation of the saw kerf to the layout line for the die opening and to the outer perimeter of the punch cutting surface.

Die Thickness Inch	Angle Of Saw Starting Hole Degree	Angle For Saw Cut, Degree	Distance From Die Layout Line To Center Of Saw Kerf Inch	Distance From Die Layout Line To Center Of Starting Hole Inch	Diam Of Drill Inch	Width Of Starting Saw, Inch	Amount Of Straight Sides On Punch and Die, Inch
1/2	21	18	5/64	3/32	1/8	3/32	3/16
3/4	18	15	3/32	1/8	1/8	3/32	9/32
1	14	11	3/32	1/8	9/64	1/8	3/8
1-1/4	12	9	3/32	1/8	9/64	1/8	15/32
1-1/2	11	8	7/64	9/64	9/64	1/8	9/16
2	10	7	1/8	3/16	13/64	3/16	13/16
3	9	6	5/32	1/4	17/64	1/4	1-1/8
4	8	6	7/32	9/32	17/64	1/4	1-5/8
5	7	6	1/4	5/16	17/64	1/4	2-1/4
6	6	5	1/4	5/16	17/64	1/4	2-1/2

Figure 1-38. Dimensional data for contour die marking.

617. State the purpose of functional tryout of machined parts and, given hypothetical situations, clarify the various causes of punch and die problems these situations reveal.

First, functional tryout; then second, the troubleshooting of machine operations are of interest to you here.

Functional Tryout. Checking assemblies for proper operation is usually the final part of your job. After you have fabricated the parts, they must fit together correctly, so that they will do the job they were intended to do. Assume that you have designed and made the parts for a die set. A die set has a number of component parts that must be assembled, such as the punch, die shoe, guide pins, springs, and various items of hardware. The only way that you can determine whether or not the die set will work is to put it together, mount it on the applicable machine, and perform a functional tryout. If everything performs correctly during the functional tryout, you have a good operational assembly. If, however, the die set does *not* perform correctly, you must find the cause of the trouble and correct it. Perhaps, for example, the guide pins are not aligned, and you must rework or reposition them. Or perhaps the clearance between the punch and the die is incorrect, and you must recalculate the clearance. In any event, your careful checking during the making of each individual part will reduce the possibility that your work must be done over.

Troubleshooting Machine Operations. One of your most important duties as a machinist is the troubleshooting of machining problems that arise during the manufacture of parts. Here, then, are some of the more common troubles, causes, and possible remedies:

- Tool chatter. *Cause*—improperly ground tools or excessive speed and feed. *Remedy*—regrind the tools correctly or recalculate the speed and feed for the material being machined.
- Inaccurate parts. *Cause*—thermal expansion, dull cutting tools, or incorrect machine adjustment. *Remedy*—use a coolant, sharpen the tools, or correctly adjust the machine.
- Failure of the punch to complete a blanking operation. *Cause*—incorrect die clearance, press not large enough, incorrect alignment of the punch and die shoe. *Remedy*—recheck the clearance, recalculate the press tonnage for the job, or check the die set alignment.
- Blanked parts stick to the punch. *Cause*—lack of a stripper or lack of lubricant. *Remedy*—providing a stripping device to remove the parts from the punch or provide a means of lubricating the material being blanked.
- Tooling marks on formed parts. *Cause*—machine tool marks on die parts. *Remedy*—buff or polish all marks from both the male and female members of the die set.
- Die set breaks down during operation. *Cause*—improper design, incorrect material, improper heat treatment, or incorrect alignment. *Remedy*—redesign the die set, select a better material for the die set, make certain that it has been properly heat-treated, or recheck the alignment.

This concludes our discussion of tool design and fabrication and, also, our study of the many machining duties you will be performing. In the next chapter, we will discuss the use of technical publications.

Exercises (617):

1. Give the purpose of performing a functional tryout of a newly assembled die set beyond just seeing whether or not it works.

2. *Situation:* You are involved in a functional tryout of a blanking die when you find that the punch does not complete the blanking operation. Cite the possible causes of this trouble.

3. *Situation:* You have found tooling marks on parts formed in a die operation. Tell how to remedy this problem.

CHAPTER 2

Technical Publications

SINCE YOUR ENTRY into the Air Force you have been exposed to a vast array of equipment. You may have observed many types of aircraft in flight or on the flightline. You probably have heard whirrs, whines, and buzzes from some of the many shops. You could have noticed some strange looking pieces of special equipment. Each piece of this equipment must be operated and maintained correctly if it is to fulfill its intended purpose. Certain information and data are required for the operation and maintenance of all this equipment. You, as an Air Force machinist, are involved in the operation and maintenance of some of the Air Force's equipment. You have probably already realized that it would be impossible to memorize the repair and servicing procedures on each piece of equipment that you must work on. To do a competent job, you must rely on guidelines, instructions, prints, etc., that pertain to that praticular piece of equipment. The Air Force publishes instructions for maintaining, repairing, and updating the equipment and systems under its control. In this chapter, we will discuss Air Force technical publications, called Technical Orders (TOs). We will also briefly examine the use of certain industrial publications that can aid you in accomplishing your assigned tasks or duties.

2-1. Air Force Technical Orders

There are many types of publications used in the Air Force, such as:

- Regulations—Announce policies, assign responsibilities, and direct action.
- Manuals—Details instructions, procedures, and techniques.
- Pamphlets—Contains information.
- Supplements—Auxiliary publications for local compliance with directives.

You have probably used most of these already. They can all be categorized as *standard publications*. Technical publications are *not* the same thing and are called *technical orders* (TOs).

In the following objectives, we will examine the purpose, scope, and application of the TO system, the TO numbering system, the filing procedures for TOs, the use of indexes for finding needed TOs, and the TO improvement system.

618. State the purpose and scope of technical orders and identify the publication stating that TOs are to be used while operating/maintaining weapon systems.

No machinist in the Air Force can function effectively without knowing and understanding technical orders (TOs) thoroughly. This BOF unit examines TOs.

Technical Orders. Technical orders are official Air Force publications which provide technical information, instructions, and safety procedures pertaining to the operation, maintenance, and modification of Air Force equipment and materials. They are intended to insure performance of our mission with the greatest possibility for success and the least chance of loss of life or damage to equipment. AFR 8-2, *Air Force Technical Order (TO) System*, leaves no doubt whatsoever that weapon systems will be operated and maintained by use of technical orders.

Simply stated, a technical order is a military order that we must follow until it has been rescinded by proper authority.

TO 00-5-1, *AF Technical Order System*, stipulates the scope, or concept, of the technical order system. It states that each individually numbered TO provides the technical information and instructions to operate, install, maintain, inspect, or modify Air Force systems and equipment. In addition, it states that compliance with Air Force TOs is mandatory and that major commands will insure that activities under their jurisdiction are aware of the need for full compliance, effective use, and economical operation of the TO system.

Technical orders, (TOs, or tech orders), are published by the Air Force Logistics Command (AFLC) and the Air Force Systems Command (AFSC). TOs are distributed by AFLC under the authority of the Secretary of the Air Force and in accordance with Air Force Regulation (AFR) 8-2. AFLC determines Air Force requirements for TOs. The major commands and the separate operating agencies assist AFLC in determining these requirements. Technical orders are the only official way that the Air Force uses to get certain kinds of information to the people who need it.

The importance of following technical order instructions cannot be overstressed. This applies to all of the various types of technical orders which we will discuss next.

Exercises (618):

1. Give the purpose of technical orders.

2. Indicate the scope of technical orders.

3. Cite the publication stipulating that TOs will be used during the operation and maintenance of weapon systems.

619. Specify the applications of the basic types of TOs, define LOAP, and cite the authorized TCTOs.

There are six basic types of publications in the technical order system. They are: (1) indexes, (2) technical manuals (TMs), (3) time compliance technical orders (TCTO), (4) methods and procedures technical orders, (5) abbreviated technical orders, and (6) automation technical orders.

Indexes. Index-type technical orders provide us with a means of selecting and locating our needed TO. Various types of TO indexes exist, such as the numerical index and requirement table (NI&RT), alphabetical index, and the list of applicable publications (LOAP). For reasons which will later on become clear, these indexes will be discussed in more depth in objective 622 later in this volume.

Technical Manuals. Technical manuals contain detailed instructions for operation, maintenance, service, overhaul, installation, and inspection. They are grouped into categories covering aircraft, missiles, special weapons, and other equipment. They are published to cover specific levels of maintenance. For example, some TMs cover *organizational level maintenance*, which is minor type maintenance. Others cover *intermediate level maintenance* (accomplished by field maintenance), which usually involves major maintenance of equipment systems or components. Still others cover *depot level maintenance*, which involves maintenance that is beyond the capabilities of intermediate level facilities at a base, such as major aircraft modifications, and overhaul. Unless you are assigned to an Air Force depot, you will not normally use depot level maintenance TOs. Exceptions are made when an intermediate level facility is maintaining some older, well-established equipment and possesses the capability to perform the depot level maintenance.

Time Compliance Technical Orders. TCTOs give instructions concerning inspections and operating procedures or provide for modifications of Air Force equipment. You can probably tell by their name that the work ordered to be done must be done within a certain time limit. These are the three types of authorized TCTOs: (1) Immediate Action, (2) Urgent Action, and (3) Routine Action.

Immediate Action TCTO. This type of TO is issued to correct existing unsafe conditions—conditions which endanger personnel and property. Requiring immediate action they can be identified by the red printing of IMMEDIATE ACTION on top of the first page. They also contain a border of red Xs on the first page. Because of the conditions for which they are issued, they ground aircraft and discontinue use of equipment. These TOs are cancelled automatically 6 months after the date of issue.

Urgent Action TCTO. This type of TO identifies hazardous conditions which may cause injury, property damage, or loss of combat efficiency. The conditions identified may be tolerated for a definite period of time. After this period, the condition must be corrected or the equipment must no longer be used. This TO is identified by URGENT ACTION printed in red on top of the first page, and alternating red diagonals and circled red Xs located around the border. The automatic rescission date of this TO is 12 months after issue.

Routine Action TCTO. This TO is issued to remedy defects of equipment or procedures. It is issued in instances when there is no immediate danger to life or property but, failure to comply with it could create a hazard, reduce operational life, or effect efficiency. Unfortunately, there is no distinguishing symbol on this TCTO like there is for immediate or urgent action TCTOs. Printed on plain white paper, it is divided into two categories. Of these, *Category I* is accomplished by organizational/intermediate level maintenance. It must be accomplished within 11 to 90 days. Failure to comply will cause the grounding of aircraft or the discontinued use of equipment. It is rescinded 12 months after date of issue. In contrast, *Category II* TCTOs are to be accomplished by depot. Such action is scheduled for the next IRAN (Inspection and Repair as Necessary) or overhaul of the particular piece of equipment. Normal automatic recision date will not exceed 48 months after date of issue.

The aforementioned are the types of TCTOs; however, another TCTO exists that you should know about. It is not a specific type of TCTO and may be in telegram, radiogram, teletype, or letter form. It is termed the "Interim TCTO." This TCTO is used when the need for instructions cannot wait for formal printing. An interim TCTO constitutes a temporary copy of an immediate or urgent action TCTO and is replaced by the printed copy within 10 workdays.

Methods and Procedures Technical Orders. Methods and procedures technical orders are general and indirective. That is, they do not deal with specific aircraft or equipment. These TOs are divided into two classes: those that involve policies, methods, and procedures relating to maintenance management or administration; and those that give policies, methods, and procedures relating to equipment in general.

Abbreviated Technical Orders. These TOs are primarily work-simplification devices. They are condensed versions of other TOs. Included in this group are inspection work cards, sequence charts, and checklists.

Inspection workcards. Inspection workcards prescribe minimum inspection requirements and are to be used while you are performing inspections.

Inspection sequence charts. These charts provide a planned work schedule or sequence, so that the inspection workcards can be used effectively.

Checklists. Checklists are lists of TO items in abbreviated form. They are used in performing various tasks or operations in a safe and sure sequence. A checklist can be identified by the letters CL followed by a number at the end of a TO number.

Automation Technical Orders. Automation technical orders consist of prepunched cards and tape decks used in electronic checkout equipment.

Exercises (619):

1. Define an LOAP?

2. State the type of technical order you would consult to find instructions for performing a major overhaul on a large cargo aircraft.

3. Identify the authorized TCTOs.

4. Indicate the type of TCTO which could be used for equipment requiring repair within 45 days.

5. Match each descriptive phrase found in column B with its corresponding TO type given in column A by putting the number-coded phrase (column B) beside its associated letter-coded TO (column A). Each phrase in column B may be used once or more than once.

Column A	*Column B*
____ a. Index.	1. Short TOs.
____ b. Technical manual	2. General, indirective.
____ c. Time compliance.	3. Locates publications.
____ d. Methods and procedures.	4. Tape decks.
____ e. Abbreviated.	5. Specific directions.
____ f. Automation.	6. General administration.
	7. TCTO.

620. Clarify the meaning of each part of the TO numbering system and identify selected documents as to TO type.

What are the various parts of the TO numbering system? They are explained here.

TO Numbering System. Each technical order has a number similar in purpose to your own serial number. This number distinguishes one technical order from another. It is usually composed of a combination of numbers and letters. The technical order numbering system is well organized and planned to provide a systematic grouping of technical publications. Each technical order number is usually divided into three, four, or five parts, discussed in that order next.

Three-part number. Technical order numbers are separated by dashes into parts. Each part has a definite meaning. One example of a three-part number is IF-105B-3.

The first part of this number consists of the *category designation* and may consist of one number, a number and a letter, or a combination of numbers and a letter. It is important for you to remember that the first part of a technical order number always refers to the category designation. The following is a partial list of categories that serve as the first part of a number:

- 0—Indexes and publications requirement tables (NI&RTs).
- 00—General publications.
- 1—Aircraft publications (including helicopter and associated equipment).
- 32—Standard and special tools.
- 34—Shop machinery and associated equipment.

These are, of course, only a few of the categories found in the numbering system. As a machinist you are concerned with the 32 and 34 category technical orders as well as many others.

The second part of a three-part number identifies a *general technical order series* or an *equipment type, model, part number,* etc. The third part of the three-part number identifies the *individual* publication.

Two three-part numbers are shown in the following examples:

- *Example 1:*
  1B-52G-3
  1B—Category designation (aircraft bomber).
  -52G—General TO series (52, model G).
  -3—Individual publication (structural repair instructions).

- *Example 2:*
  32B6-2-14
  32B6—Category designation (hammers).
  -2—Equipment type (pneumatic).
  -14—Individual publication (type II pneumatic hammers).

Four-part number. Let's look at the parts of the four-part number more specifically.

a. The *first part* of the number (the part designating the category) normally consists of three designators. These break down as follows:

- The *first designator,* which is numerical, identifies the *category* of technical orders. Here are two examples:

32—Standard and special tools publications.

34—Shop machinery and equipment publications.

- The *second designator,* which is alphabetical, identifies a *major group* of publications. Here are two examples:

32B—Standard tools.

34C—Cutting machines

- The *third designator,* which is numerical, identifies a *major subgroup* of publications. Here are two examples:

32B6—Hammers.

34C2—Metal-cutting machines.

b. The *second part* of a four-part number identifies a particular usage or subtype of equipment. Look, for example, here:

34C2-8—Saws

c. The *third part* of a four-part number identifies a general technical order series or an equipment type, model, part number, etc. One example follows:

34C2-8-3—Type C-3.

d. The *fourth part* of a four-part number identifies an individual publication. These are examples:

34C2-8-3-1—Opr/Svc.

Instr-contour sawing machine, 16-inch, type C-3 (Do-All Model LHF)

Five-part numbers. The Air Force currently uses five-part numbers in some categories. They are used to further breakdown an equipment group that is too complex for the four-part number to handle. The index for the specific category explains the parts of a five-part TO number.

Examples of the TO numbering system. If you understand the technical order index numbering system, you can identify the types of TOs by the number. Some examples of TO numbers that are typical of the different types of tech orders are these:

a. Indexes:

TO 0-1-01
TO 0-1-02
TO 0-1-2
TO 0-1-4
TO 0-1-34
TO 0-2-1
TO 0-3-1
TO 0-4-1

Notice that all of these TO numbers start with zero.

b. Technical manuals:

TO 1F-4C-4-1
TO 1F-105B-1
TO 21M-CGM16E-06-2
TO 33D5-2-14-8-1
TO 34C2-8-3-1

Notice the lack of similarity in these TO numbers.

c. TCTOs:

TO 1B-47-1200
TO 1B-58(T)-A-518
TO 1C-135B-527
TO 1F-4-523
TO 1F-100-923

Notice that all of these TO numbers end with a large number (TCTOs are numbered consecutively, starting with 501).

d. Methods and procedures:

TO 00-5-2
TO 00-20E-1
TO 00-25-06-2-2
TO 00-35D-1

Notice that all of these TO numbers start with double zero.

e. Abbreviated technical orders:

TO 1B-52G-6CF-1CL-1
TO 1C-119C-6WS-1CF
TO 1F-105B-6SC-1PE
TO 33AA7-44-6-WC-1

Notice the use of capital letters to identify the kind of abbreviated technical order; i.e., CL for check list, WS for inspection worksheet, SC for inspection sequence chart, and WC for inspection workcard.

The Air Force has the continuing problem of keeping the information in technical orders current. Why? Because, for example, the equipment manufacturer finds the solution to a problem, and the TO must be modified accordingly. Again, policies and maintenance procedures change; here, too, the TO must be altered. Or new equipment is introduced into the Air Force inventory. Thus, whichever of these situations arises, technical orders must be updated continually in order to incorporate this new and later information. All right, how are TOs modified? Answer: Several methods are used for this purpose, and we will discuss these methods in our next learning objective (621).

Exercises (620):

1. Tell what the first part of a technical order number designates.

2. State which part of a three-part number identifies an equipment type or model.

3. Identify each of the following as to its type of technical order:
   a. 1C-135B-520.

b. 0-1-32.

c. 1F-F4E-6CL-1.

621. Give the applications and filing procedures for TO changes, revisions, supplements, appendixes, and recisions; and, provided typical situations involving these TO alterations, resolve each correctly.

Our subjects in this segment of the text are TO change, revision, supplement, appendix, and recision procedures.

Changes. Changes to technical publications are issued when only parts of the technical order are affected. In such cases, the words "Change Notice" are printed across the front of the change. Also, the supplements changed by the notice are identified by number on the title page. The date, given in large print in the lower right-hand corner of the title page, identifies the date of the basic TO; whereas the date printed in smaller print indicates the date of the change. Each page that is changed by the notice also has the date of the change printed on it.

To insert a change into a technical order, first, remove the page (or pages) from the technical order having the same number as the change page and insert the change page into that place. Second, after you have placed the change in the technical order, turn to page "A" (which is included with the change package) of the technical order. The "A" page lists the effective pages of the TO and the date of each page. Any page listed with an asterisk (*) beside it is a page that is affected by this latest change. Third, check the date of each page in the TO against the date for that page as listed on page "A." The dates must be the same. If the dates are *not* the same, the TO is not current.

Carefully read the title page of the change. Remember that if any supplement is included in the change, the affected supplement is identified on the title page. Sometimes the title page will state that a particular supplement is not included and that the supplement is to be retained. Do not assume anything. Just because the change date is later than the date on a supplement does not mean that the change automatically supersedes the supplement.

Revisions. A revision is a new edition of an existing TO. It has a new basic date. A TO is revised when a change affects 80 percent or more of the TO, or the TO has eight or less pages. A revision contains all of the latest changes, appendixes, and supplements (except as noted on the title page). Again, you can see that you must read the title page. You will find that some revisions replace other TOs and incorporate them into the revision. If this is so, remove the replaced TO from the file.

Supplements. Supplements are issued as separate technical orders to the basic TO, or they change data in the basic TO. Supplements are of two types—cumulative and noncumulative. Of these, a *cumulative supplement* includes all of the information contained in previously issued supplements and replaces them. Read the title page to see whether or not any supplements are included in the cumulative supplement. In contrast, noncumulative supplements do not contain any previously issued supplements, and they only replace those items listed on the title page.

Supplements have the same TO number as the technical orders they supplement, except that a letter is added to the end of the TO number. Also, the word SUPPLEMENT is printed in heavy black type at the top of the title page. Three *basic* types of supplements exist: (1) safety, (2) operational, and (3) routine—discussed in that order next. Then interim and formal supplements are covered.

Safety supplements. These supplements are used as a quick way to distribute safety information correcting a TO deficiency. By this we mean that the technical order, if followed as written, could constitute a hazard. The information contained in the safety supplement is incorporated into the original TO at the next revision of the TO. When this takes place, the title page of the revision or change states that the safety supplement has been included and the safety supplement is to be removed from the file.

Like other supplements, safety supplements have the same TO number as the TO they supplement. The letters SS are added to the TO number to identify the publication as a safety supplement. The last number in the safety supplement number indicates the number of that supplement. Thus, for example, the first safety suplement to TO 1F-106A-1 would be TO 1F-106A-1-SS-1; the second would be TO 1F-1206A-1-SS-2; and the third, would be TO 1F-106A-1-SS-3.

Operational supplements. These supplements are issued as a quick way to reflect information when work stoppage or operational defects related to the accomplishment of the mission are involved. The information contained in operational supplements is incorporated in the original TO when the original TO is revised or changed. Operational supplements are numbered in the same way as are safety supplements, except that the operational supplement uses a single letter S rather than the double SS. The reason for not using OS is that the O might be read as a zero instead of the letter.

Routine supplements. Routine type supplements are issued only to supplement NI&RTs, TCTOs, and publications, such as commercial manuals and Army technical manuals which are normally permanently bound.

Interim and formal supplements. Safety and operational supplements are issued in two ways: (1) interim and (2) formal. Of these, interim supplements are issued by electrical transmission to the headquarters of the using commands. The headquarters passes the information on to all affected activities of the command. Interim safety supplements are issued when safety conditions exist which could result in fatal or serious injury to personnel, or when extensive damage or destruction of property or equipment is involved. Interim operational supplements are issued to correct conditions when the using command is unable to achieve or maintain mission capabilities.

In contrast to the foregoing, formal safety supplements are issued when a potentially hazardous condition could result in injury to personnel or damage to property or equipment. Formal operational supplements are issued when a condition could reduce operational efficiency or jeopardize safety. Safety supplements have a border of red SSs around the edge of the title page. Operational supplements have a border of black OSs around the edge of the title page. Supplements should be filed in front of the basic technical order in reverse numerical order. In other words, the latest supplement should appear first. Both operational supplements and safety supplements are numbered, too, each in the same sequence. For example:

TO IF-4C-1-FS-1
TO IF-4C-1-F-2
TO IF-4C-1-S-3
TO IF-4C-1-SS-4.

Appendixes. An appendix is used to include material (such as charts and tables) in a TO that is not a part of the normal sequence, as outlined in the table of contents. Appendixes are issued as part of the basic TO or separately at a later date. An appendix issued later than the basic TO includes additional information and contains a new title page. The appendix portion is inserted at the end of the TO, while the title page is inserted at the front.

Recisions. A technical order is rescinded by the Air Force when (1) the information contained in the TO is no longer required, (2) when the TO is incorporated into another technical order, or (3) the recisions date of the TCTO has expired. Keep the TO in the file until the TO is listed in the NI&RT as rescinded.

Exercises (621):

1. Differentiate between TO changes and TO revisions.

2. *Situation:* You are filing a change in a TO when you notice that the date of the change is later than the last two supplements. State what you should do with the supplements.

3. Indicate where you should look to find the extent of a new revision before you file it.

4. Distinguish between cumulative and noncumulative supplements.

5. *Situation:* You must tell, simply by looking at the number of a supplement, whether it is an operational or a safety supplement.Tell how you would do this.

6. Clarify how supplements should be filed in reference to the TO.

7. *Situation:* You find a new title page included in a package containing a new appendix. Indicate why this has been done.

8. Reveal how long you should keep a rescinded TO on file.

622. State the characteristics and purpose of the various types of TO indexes and, given typical situations involving particular TO indexes, resolve each correctly.

What types of indexes exist or are of concern to you? This BOF segment tries to answer these questions.

Types of Indexes. Technical order indexes contain information about the status of all TOs. You use these indexes to select the individual TOs you need. In certain instances, indexes list the TOs in groups that pertain to specific items of equipment. In fact, there are several types of indexes, all of which are discussed in the following paragraphs.

Index to the indexes. The person who maintains the TO library uses TO 0-1-01, *(Numerical Index and Requirement Tables, Numerical Indexes, Alphabetical Indexes,* and *Cross-Reference Tables Technical Order).* This TO is sometimes termed the "index to the indexes," since it contains a list of all of the indexes (NI&RTs). The information found in this index is arranged in columns. Starting from the left, the columns are: (1) the Index Number column, (2) the Title and Class Identification column, (3) the Basic

Date column, (4) the Storage and Issue column. Of these, the Number column contains the index number and identifies the TO as classified or unclassified. Also, by means of asterisks or alpha symbols, this column specifies the extent of index distribution and whether an index TO is new, published, or unpublished. A complete explanation of the codes and symbols used can be found in the front of the index, in the preface. These explanations apply to all NI&RTs. The Title column lists the title of the index and the classification of the index (if any). The Basic Date column lists the date of the basic index and lists, too, the latest change number date. The Storage and Issue column lists the alpha code for the Air Force Logistics Center (ALC) that has storage and issue responsibility for the index.

The index to the indexes (0-1-01), as well as all NI&RTs, contains a list of any and all rescinded or cancelled publications that would normally be listed in the index. You use the index to the indexes to obtain the number and currency of other indexes. TO monitors also use it when they order NI&RTs for various TO categories.

Numerical Index and Requirement Tables (NI&RTs). These NI&RTs consist of a combined numerical listing of TOs applicable to a specific category of equipment or to classes of publications. They also contain data used to establish initial distribution requirements and to requisition TOs, as stated in TO 00-5-2 *Distribution and Storage of Air Force Technical Order System Publication.* Each NI&RT contains the same type of information as does the 0-1-01, as just discussed, except that they list specific TOs instead of indexes, as the columns are arranged in the same way and the codes and symbols have the same meaning as in TO 0-1-01. You use the NI&RTs to determine the availability and status of publications for requisitioning TOs and for maintenance of TO files.

Alphabetical listing of equipment to technical publication number groups. TO 0-2-1 is an alphabetical index of categories for technical publications. It provides you with an easy way for you to locate the correct TO number group when you know the type of equipment.

Cross-reference tables. TO 0-4-2 contains tables for cross-referencing time compliance TO (TCTO) numbers to the applicable data code numbers. There are two complete tables in this index. The *first* table is listed by TCTO numbers and, in contrast, the *second* table has the same information listed by TCTO data code number. The data code must be used when you report the accomplishment of a TCTO, and this index provides quite a convenient method of obtaining the correct data code.

List of Applicable Publications (LOAPs). These TOs contain listings of all technical orders applicable to the specific equipment covered. You use LOAPs to select and become familiar with publications on specific Air Force equipment in which you have a responsibility. When you establish a limited TO file, use the appropriate LOAP to determine the contents of the file.

Exercises (622):

1. Name the publication containing a list of all NI&RTs.

2. Indicate the information the Storage and Issue column in TO 0-1-01 contains and how it is listed.

3. *Situation:* You have been given the task of maintaining a TO library. Tell what you will use the NI&RTs for.

4. Relate when an alphabetical index, such as TO 0-2-1, would be most helpful.

5. *Situation:* An Air Force organization on your base has received a new piece of equipment that has several components—each of which may or may not be covered by separate TOs. State how you can determine which TOs are applicable to the equipment.

623. Clarify the procedures for using TO indexes and cross-reference tables to locate required information, identifying the NI&RTs on selected topics and, given hypothetical situations involving these NI&RTs, resolve each correctly.

Every machinist needs to know how to use TO indexes and cross-reference tables; otherwise he cannot perform his job effectively. This unit examines these things.

Uses of TO Indexes. There are 90,000 individual publications in the Air Force Technical Order System. These many publications are arranged in groups termed "categories." A category is a related grouping of technical orders by subject or equipment. As we have already stated (in our objective about the TO numbering system), each category is identified by a number and a title. Each of these categories has an index for identifying and locating the various technical orders within the category.

Consider this, for example: TO 0-1-1 is the numerical index of aircraft TOs (category 1), TO 0-1-2 is the numerical index of aircraft engine TOs (category 2), and TO 0-1-8 is the numerical index of airborne electrical systems TOs (category 8). Of course, these titles are not the *exact* titles of the indexes. They are near enough, however, to give you the idea of the type information contained in each. These indexes are NI&RTs, they are used in the same way that the 0-1-01 is used;—i.e., to determine the currency of the specific TO and to requisition TOs.

It is possible for you to use NI&RTs to identify the TOs containing information about a specific piece of equipment when the technical order number and title are not known. How would you do this? Simple, you must determine the category that contains the information. To do this, *first*, look in TO 0-1-01 and use its table of contents to find the part of the index that contains the list of numerical indexes. Then, *second*, turn to the page indicated in the table of contents and read through the list of categories given there until you find the one that best describes the specific piece of equipment you are looking for.

The technical order number for each of the category indexes is formed by adding the category number to 0-1, right? Okay, then, the category index for Standard and Special Tools (category 32) will be 0-1-32. Here the 0 indicates an index, and the -1 indicates that the index is a general index.

After determining the category number, third, look in the index of that particular category and consult its table of contents. In this table you will find the desired title. For example, suppose you need information on a Model ML Contour Sawing Machine manufactured by the Do-All Company. First, you must determine the category in which the contour sawing machine would be classified. By looking in TO 0-1-01, you will find the different categories of equipment. Since a contour sawing machine would probably be classified as "shop equipment" or "shop machinery," look for a category that pertains to this type of equipment. As you scan the listing you will come to Insp. Laboratory, Acft, Accessories, Acft, Engines, etc., Shop Machinery, and Associated Equipment, (category 34). Good, by adding the 34 to 0-1, you will obtain the numerical index number for shop machinery and equipment; i.e., TO 0-1-34.

Next, fourth, turn to the table of contents of TO 0-1-34. You will find metal-cutting machines listed under 34V2 series TOs. The information for each model of metal-cutting machine is given. As you look over various metal cutting machines, you will find metal-sawing machines listed. A closer look at the listing will reveal to you that the Do-All Model ML instructions are listed in TO 34C2-8-3-24.

Naturally, TO-0-1-01, the *Numerical Index of Indexes and Publications Requirement Tables,* does not list all publications. Publications of a general nature are listed in TO 0-1-02, *General Publications Index.*

The TO 0-2-1 *Alphabetical Index* is published to provide personnel with a quick method of determining which category is related to a certain item of equipment. Use this publication just like you use a telephone directory. You will find it very useful if you know the name of the item. For example, say you want to locate information on the operating and servicing instructions for a Hobart Model GR-315 Portable Arc Welder. Since publications are listed in the alphabetical index under captions which indicate the name of the equipment, you should, first, turn to the caption section to find that the technical order category for this equipment is 34W4. You would then, second, have to use TO 0-1-34 to determine the complete technical order number for the welder. In this case, it would be TO 34W4-3-1.

Alphabetical indexes are often not as current as the numerical indexes; therefore, they should not be considered the final authority on whether specific publications exist. Consequently, if the publication is not found in TO 0-2-1, consult TO 0-1-01 before deciding that there is no information available.

Since the alphabetical index does not contain the complete TO number, there is no need for it to have a basic date column. In the example just given, TO 0-1-34 has the basic date column that lists the date TO 34W-3-1 was published. The alphabetical index is not used to requisition TOs.

Two cross-reference table TOs exist; they are: (1) TO 0-4-1 and (2) TO 0-4-2. As we have already stated, TO 0-4-1 contains a complete list of all Air Force technical publication numbers which were affected by the renumbering program. This consolidated list replaces the individual lists formerly found in Part III of each numerical index. Therefore, use TO 0-4-1 to change old TO numbers to new numbers. In certain instances, though, it was necessary to renumber a publication more than once. Thus, the entry:

03-75D-2 15H6-3-2-3 8S6-2-2-3

means that the publication was originally numbered 03-75D-2, then renumbered to 15H6-3-2-3, but is presently identified by number 8S6-2-2-3.

Earlier we told you that TO 0-4-2 contains listings of active TCTOs and overhaul change TO numbers cross-referenced to applicable data code numbers, and data code numbers cross-referenced to active TCTOs and overhaul change technical order numbers. Note that data code numbers do not appear in other tech order index publications.

The purpose of this cross-reference table is to identify data code numbers assigned to action TCTOs and overhaul change TOs. The use of data code numbers for control and reporting of TO accomplishment is outlined in AFM 66-1, *Maintenance Management.* For example: when you complete the work required by a TCTO, you must make certain entries on the maintenance form. One of these entries is the data code number used to identify the TCTO. In many cases, this identification code number is not available when the work is assigned. You use TO 0-4-2 to determine the applicable TCTO identification code number. In addition, the data code number is used to identify TCTO kits. The use of the data code number to identify TCTO kits is outlined in AFM 67-1, *USAF Supply Manual.*

Exercises (623):

1. Give the number of the NI&RT which covers the category for shop machinery and equipment (34).

2. *Situation:* You have located the correct index for a category of TOs that includes the equipment you must work on. Tell your next step.

3. State why you should check TO 0-1-01 if you cannot find a certain publication on equipment in the alphabetical index.

4. *Situation:* You must obtain a TCTO data code to fill out a maintenance form, but it is not on any of the information you received with TCTO kit. Point out where you should look to find the exact data code for the TCTO and kit.

624. Specify selected uses of TO improvement reports and, given a typical situation involving such use, resolve it correctly.

What is a technical order improvement report and how is it used? These are discussed here.

Technical Order Improvement Report. You and I are responsible for reporting any required change to a TO that we discover. The change will be submitted on an AFTO Form 22, Technical Order System Publication Improvement Report and Reply. To complete this form, you must consult TO 00-5-1, *AF Technical Order System.* Most of the blocks on the form that you will be required to fill out are self explanatory; however, command designators are required, and they must be obtained from the TO. Also, by referring to the TO each time you submit an AFTO Form 22, you will be alerted to any changes in the procedure that might have been initiated since the last time you submitted one.

When you submit an AFTO Form 22, the change that you are requesting will fall into one of these three types: Emergency Reports, Urgent Reports, or Routine Reports.

Emergency reports. These reports require immediate correction to a TO deficiency involving safety and unit mission. Why? Because failure to make the correction would result in fatal or serious injury to personnel, extensive damage or destruction of equipment or property, or inability to achieve or maintain operational posture (MISSION ESSENTIAL). The activity responsible for corrective action must respond within 48 hours by issuing a TCTO or by disapproving or downgrading the report.

Urgent reports. Urgent Reports recommend nonemergency TO deficiencies involving hazardous conditions. These conditions could result in personnel injury, equipment damage, or prevention of safe mission accomplishment. These reports must be answered by the responsible activity within 30 calendar days. This includes printing and distribution time. The activity will reply within 20 days if the action cannot be completed within 30 days or if the report is disapproved or downgraded.

Routine reports. These reports are recommended improvements to TOs to correct potential hazards. These hazards may result from prolonged use and have a negative effect on operation or maintenance efficiency. They may also reduce the life or general service of the equipment. These reports, with few exceptions, will be replied to within 60 calendar days by the responsible activity.

Exercises (624):

1. *Situation:* You notice a procedural error in TO and wish to correct it. Relate the way to submit a change request.

2. Name the publication you must consult to obtain the applicable command designator for filling out an AFTO Form 22.

3. Cite the conditions in which you would submit an emergency type AFTO Form 22.

4. Tell how long you should expect to wait for a reply to a routine report AFTO Form 22.

2-2. Industrial Publications and Manuals

As a machinist, you will find that you will have to refer to industrial publications from time to time to obtain information on machining techniques or procedures and to obtain operational and maintenance information on some new type of machinery or equipment. In this section we will briefly discuss some of these publications.

625. Identify selected characteristics and applications of machinist handbooks and manufacturer's publications and, given a typical situation involving such publications, resolve it effectively.

Next to be discussed are machinist handbooks and manufacturer's publications.

Machinist Handbooks. Several machinist handbooks can be found on the market, but perhaps the most popular is the *Machinery's Handbook*, which is published by the Industrial Press. If your shop does not have a copy of it or a similar publication, you can usually obtain it through the base library. It will be assigned to the shop, and you can usually arrange to get an automatic delivery of new editions as they are published. Although our discussion of handbooks will be concerned mainly with the *Machinery's Handbook*, the information applies to most machinist handbooks, since they are very similar in the way they are used in content.

Perhaps the most used portion of these handbooks is the area containing the many mathematical tables. These tables include such information as the square, the cube, the square root, and the cube root of numbers up to 2000 (whole numbers, decimal numbers, and fractional numbers); surface and volume of spheres; logarithms; trigonometric functions; and many others. In addition, formulas for calculating area, circumference, diameter, and volume of various shapes (squares, rectangles, parallelograms, trapesoids, circles, triangles, etc.) are listed and explained. These tables and formulas are very useful when you must calculate the various dimensions for machining gears, helical reamers, etc. They are also very useful when you must machine angular work.

In addition to the numerous tables and formulas, you can find information about the strength and adaptability of metals and the recommended speeds and feeds for machining them with various kinds of machines. You can find information about how to make machine setups for many difficult machining projects such as helical gears and cutters. Also, complete thread specifications are listed for nearly every kind of commonly used threads (American National and Unified forms, British metric forms, Pipe forms, etc.).

Even if you have not yet looked through a copy of the *Machinery's Handbook*, you can see from the foregoing that there is a tremendous amount of information packed into it, even though what we have mentioned heretofore constitutes only a tiny portion of the total. In fact, the 19th edition contains some 2420 pages of information. "All right," you ask, "how do I find anything in it without thumbing through all of those pages?" The logical answer would be for you to turn to the table of contents. However, that is not the best way available since the table of contents is both very general and is arranged in numerical sequence of pages instead of alphabetical. Instead, the best way to use this volume is to turn to the back of the book, where an alphabetical index is located. This index is very extensive and lists all of the subjects covered within the volume. Also, a special metric index is included that references the many instances where metric measure is used, cross referenced, explained, etc., throughout the book.

At first glance, machinist handbooks look extremely difficult to understand, but if you will use them, you will find that they can be an invaluable aid during your work as a machinist. They are really quite easy to understand. In fact, they go to great lengths to explain every subject fully.

Manufacturer's Publications. Most machine shops have manufacturer's service manuals for the machines and certain other equipment in the shop. These manuals are necessary for obtaining the specific lubrication requirements, adjustment procedures, and overhaul prints and techniques for each particular type of machine. In most cases, these manuals should be considered as official TOs. When the Air Force purchases a piece of equipment, the manufacturer normally furnishes a service manual which is then given a TO number. This number should be entered on the upper right-hand corner of the cover or front page of the manual. The date the number was assigned should be in the lower right-hand corner of the same page. If your shop has manuals on hand without a TO identification number, you should research the NI&RT applicable to the type of equipment. Usually, it will be listed, and you can then properly enter the TO number and date on the manual. If it is not listed, you should consult TO 00-5-1 for procedures to follow to obtain a TO identification number.

In addition to maintenance information, manufacturer's service manuals many times contain information about special uses of the equipment. A careful study of these manuals will often reveal timesaving shortcuts for accomplishing certain tasks on the equipment. At least, you will gain a knowledge of how the equipment is designed and put together. This will help you to use it more efficiently and aid in your understanding of the preventive maintenance measures specified within the manual.

Exercises (625):

1. State the area of the *Machinery's Handbook* or similar publication which is normally used the most.

2. Tell how the *Machinery's Handbook* or similar publication can be of help to you in the setting up of a machine for cutting helical gears.

3. Give the best way to find specific information in the *Machinery's Handbook*.

4. Name the type of manufacturer's publications you, as a machinist, will probably have most contact with.

5. *Situation:* You know that your shop has a manufacturer's manual for a piece of equipment, but it does not have an TO identification number stamped on it. Tell what you should do to correct this situation.

6. Relate the advantages you gain by skillfully studying manufacturer's publications for assigned equipment.

Supervision and Training

"WHY SHOULD I STUDY supervision and training? I'm not the boss." This is often the attitude taken by an apprentice specialist, and, as of now, it may be true in your case. But let's look at the facts.

As you train toward the 5 skill level, you are being supervised very closely, and your training program is outlined for you in great detail. After you reach the 5 level, your duties will include training apprentice specialists, just as you are being trained now. During the training, you will be responsible for their immediate supervision. It will also be your responsibility to develop training programs to aid your trainees in their upgrading.

With this in mind, let us look at some principles of supervision that will be of benefit to you and see how the Air Force training program works.

3-1. Supervision Concepts

The odds are highly in favor of your being a supervisor at some time during your first tour of duty. Your first job as a supervisor may be training an airman just arriving from technical school. Your next job may be as a shift supervisor, or even as a supervisor of the whole shop.

You may ask, "What is a supervisor?" Answer: A supervisor is an individual who directs the efforts of one or more people in getting a job done. He is a leader and a manager. He assigns the man, lays out the details of the job, assures that the man receives necessary training, and sees that equipment and materials are assembled to perform the job. The quality of his supervision is measured by the degree of success of his unit. He must account for the time of his workers and the materials they use. Here are three broad areas that the supervisor must understand if he is to perform his mission: *responsibilities, employee relations,* and *production.* Keep these areas of supervision in mind as we complete this chapter of this volume.

626. Relate the reasons for coordinating work with other shops and why supervisors must coordinate actions much of the time, and identify the agencies responsible for work coordination.

You must at some time coordinate your shop's work with that of others; so we will take up coordination here.

Coordination. Today's Air Force is made up of people with many AFSCs, many of them trained to accomplish this work or that in a certain area of aircraft maintenance. This includes specialists in aircraft electrical, hydraulics, engines, and fuel systems, and many others, as well as your own.

During an inspection, many of these specialists will be required to perform work on the aircraft. If all of these people were to attempt to complete their required work at the same time, you can well imagine the confusion that would be created. To avoid this and still accomplish the work in a timely manner, coordination with the other working shops is required. The coordination is usually accomplished by job control. Their assignment is to schedule people, equipment, aircraft, and jobs.

There may be occasions when you need an electrician to help you complete a task. First, you must explain the situation to your supervisor. Second, he, in turn, will check the job and then, third, arrange through job control, to have the needed specialist dispatched from the electrical shop.

Your supervisor spends many hours each week in one phase or another of coordinating. Training schedules, work programs, and assigning workers to jobs and shifts all require coordination to achieve a well-balanced, smoothly operating organization.

Exercises (626):

1. Give the reasons for coordinating work with other shops.

2. Identify the one central agency that has the primary task of coordination in maintenance organizations.

3. State why the supervisor must spend much of his time coordinating actions.

627. Cite resources considered in planning operations and the reason for correctly aligning scheduling and priorities and give the factors involving personnel resources to evaluate when planning/scheduling a long-term job by a work crew.

Along with coordinating, supervisors need to plan and schedule work assignments and priorities—our next topic.

Planning and Scheduling Work Assignments and Priorities. If you become the supervisor of a machine shop, you will quickly realize that you must run a shop that fully supports the mission of your base. But the way your shop operates will be the result of your decisions as supervisor, and your decisions will be affected by the size and layout of the shop facility, the workload, the capabilities of your people, the type and condition of the equipment you have available, the extent of supply support that you receive; in other words, by your entire repair capability.

This means that, as task requirements arise, you must plan and schedule work assignments and set priorities. When planning to meet your objectives, you must check your resources, which are manpower and equipment.

1. *Manpower* includes unskilled labor as well as highly trained personnel. Accordingly, you must not use 3-level personnel for difficult tasks nor must you use 7-level personnel for simple tasks. This means to choose the right man for the job.
2. *Equipment* also is very important. After all, you cannot complete a task effectively without using the proper tools. Past workloads should help you as you plan your manpower and equipment for best utilization.

When planning an operation, however, you have to consider scheduling. Consider, for example, that you may have to schedule the use of maintenance stands or low stage air compressors with another section. Also, of course, you have to schedule your personnel for *chow*, as well as may have to fit it around other specialists working in the same area.

You cannot skip priorities, either. They must also be considered when you are planning and scheduling. Remember, your primary concern is to keep aircraft flyable. Therefore, when you schedule priorities, you need to schedule your personnel according to daily commitments. Here, for example, work on aircraft which are scheduled for flight would be of the highest priority; whereas work on an aircraft in a phased inspection as well as in-shop work would normally be of lower priorities.

Therefore, when you have done the proper planning, scheduling, and aligning of priorities, you will get the most out of your available resources. True, you may need refinements here and there, but you can make these changes as necessary. Let's look at a situation. Assume that an important TCTO project has come up that you have not foreseen. Also, assume that the time of year has arrived when people want to take leave, and you have been assigned the responsibility for the new special repair program. You are in luck here. Why? Because Sergeant Smith, one of your senior NCOs, has volunteered to supervise accomplishment of the TCTO which will involve all of a specific type of aircraft on your base. Okay, in your planning discussions with Sgt Smith, you find that he feels that he and one other person should be able to complete one aircraft in about 4 hours. Now, knowing all of this, you must plan and schedule the work.

But wait a moment. Think, you must consider several other things when you plan and schedule the work. For one, you must keep enough people available for other unscheduled priority work that may come up. You must also consider the training requirements, appointments, and details that must be met during the time that the TCTO will be in progress. In addition, don't forget about the leave requests of some of your personnel! As you can see, then, this job of supervising is not as easy as it looks.

Two things more to remember that will dictate part of your scheduling are the time limit in which you must do the work and the way that Job Control will be able to schedule the aircraft for the work. Here is a prime example of the coordinating abilities you must possess as a supervisor. When Job Control informs you that they will be able to schedule three aircraft per day until the job is complete, you arrange to have only two aircraft scheduled on the first two days. Why? Simply to allow time for training extra personnel in case of emergencies, which could require replacements.

All right, assume that you have decided which people should be trained on the job. At this point you must give Sgt Smith the *authority* to accomplish his job. This is difficult for some supervisors to do. Still, you can't expect Sgt Smith to do his best work if he has to call the shop and check with you before he makes each move. Therefore, let *him* brief the people that are to be trained, and, as far as possible, also allow him to choose the person he wants to help him accomplish the task. In addition, permit him to coordinate with the other shops for whatever equipment he might require. If you do these things, he will take much more pride in his work, since he feels freer, more self-assured being allowed to exercise his initiative in this way.

Don't relax entirely here, though. Sure, you know that Sgt Smith is extremely capable. Still, you must not feel that your job is over at this point. It is your responsibility, too, to monitor the entire program to insure that the project stays on schedule. Also, you will find that an important part of your job as supervisor is to brief your superiors on the progress and estimated time of completion of the various projects being accomplished by your shop. Therefore, you must know at all times how the work is progressing, what problems have been encountered, what is being done about them, how the completion time will be effected, etc.

If you have planned and scheduled your work assignments and priorities properly, the TCTO will be accomplished successfully without severe hampering of your normal workload. However, if you approach the situation with the attitude that long-range planning isn't necessary and that everything will fall into place if you just take each day as it comes, you will instead find yourself failing in most aspects of your assigned mission.

Exercises (627):

1. Name two resources that must be considered when you plan an operation.

2. Give the reason for the importance of proper aligning and/or scheduling priorities.

3. Give the factors concerning personnel resources you should evaluate when you must plan and schedule a work crew to accomplish a long-term task.

628. Concerning assignment of personnel to maintenance and repair tasks, state the factors to consider and the difference between "skill level" and "experience" and, given a hypothetical situation involving personnel assignment, resolve it effectively.

Our next subject is the assignment of personnel to maintenance and repair tasks.

Assigning Personnel to Tasks. As with any part of supervision, certain factors govern our decisions when we must assign work. Three such factors which we will discuss are: skill level and experience, job priority, and work distribution.

Skill level and experience. You know by now that all of our tasks are not always the same nor is everyone equally trained in all of the areas of responsibility. Therefore, as we receive work orders for dispatching, we must think very carefully about which worker we want to dispatch. We want to assign a specialist who can accomplish this task without much trouble. Okay, what factors must we consider in order to select this person? First, consider what is termed "skill level." Obviously, we must assign a person to each task whose skill level is commensurate with that task. This means that we would not send a newly assigned 3-level apprentice out to the flightline alone to remove and replace some damaged studs. However, it is not enough either that a person holds a 5 or 7 skill level; this does not always mean that the job *must* go to that person. Why not? Because this is where what we can term "the experience factor" comes into the picture. Look, for instance, at the situation where your shop has been making a particular type of micrometer inspection on different aircraft over a period of weeks. Now, the same job comes up again. Question: Who should you send to do this new job? Say that you have, on the one hand, a 3-level apprentice who has been signed off in the JPG as being qualified for this task and, on the other, a new 5-level machinist—one who has not worked around this type of aircraft before. Answer: Clearly, based just on experience, the best person for you to send here would be your 3 skill level apprentice. Surely, the 5 skill level machinist could more than likely figure the job out, since he possesses the skills and training to do so. Still, given this situation, the 3 skill level apprentice would probably be able to accomplish the job quicker. In fact, time can be especially important when the work is of a high priority, and priority is the next factor we will discuss.

Job priority. Why does the job priority influence our work assignments. Answer: Simply, because of mission essentiality. So if a job has a priority, it may be necessary for you to assign your best specialist for its quick completion. However, if you have a lower priority job, you may be able to assign a less experienced specialist and, at the same time, broaden his/her experience and knowledge. In the example given a while ago involving a micrometer check, if the priority for the check is low, you would probably be better advised to send the 5-skill level person out, thus enabling him/her to gain the needed experience so he/she could be prepared for future higher priority jobs. But hold on, you still have the one other factor to consider: work distribution.

Work distribution. As you can probably see by now, you must consider all of these factors together, not separately. In our previous example, the workload of the shop would make a difference as to how you assigned the job. Accordingly, if the workload were not too heavy, probably your best course of action would be to send *both* the 3- and the 5-level airmen out on the job. In this way, the 5-level machinist could gain the needed experience, yet the job would still be accomplished quickly. However, if one of these two individuals was already working on an in-shop lathe job while the other was keeping busy by cleaning machines, it would not be wise for you to take the person off the lathe job when the one cleaning machines could handle the work order.

Another part of the work distribution factors is dividing the work evenly and fairly. This means that you must not show favoritism by always assigning the better or cleaner jobs to certain individuals. This is especially true concerning several individuals who have the same skill levels. Why? Because by failing to distribute work evenly and fairly, you can cause hard feelings between workers, making them unhappy. Consequently, a drop can occur in the quality of work produced by your shop.

These, then, are the basic factors involved in assigning personnel to various maintenance and repair tasks. Of course, the different personalities of the personnel involved may create other factors which you must learn to handle through experience. But that is another story. In any event, it is very important in supervision to handle every situation according to the circumstances involved.

Exercises (628):

1. Cite the basic factors to consider when assigning personnel to various maintenance and repair tasks.

2. Differentiate between *skill level* and *experience* where work assignments are concerned.

3. *Situation:* As the shop supervisor, you receive two high priority work orders at the same time. The first task is to remove several screws from an aircraft wing. The second is a recurring job to remove a broken stud from an area that requires the use of a special jig. You find that you have one experienced 5 level, a newly assigned 5 level, and an untrained 3 level available for work. Indicate how these people should be assigned to the two jobs.

629. Give the reasons for supervisory inspections, both of completed work and in-progress work and, given a hypothetical situation, identify the error, if any, the supervisor has made.

Every supervisor must know how to conduct supervisory inspections. Let's look at these at this time.

Supervisory Inspections. When you inspect a completed task, give it a thorough examination—not just a quick *once-over.* There are at least two good reasons for making such a thorough check. They are these:

First, the equipment that has been worked on must operate properly for the success of the mission, and it must be in safe operating condition. *Secondly,* inspection of completed work may be turned into an excellent learning device for those in training. Your method or technique of reviewing completed work determines the inspection's usefulness as a teaching device. Where is a better place for the trainee to learn than on the equipment?

Reviewing a completed assignment requires a considerable amount of skill and tact as well as a thorough understanding of the mechanics of the job. As you talk to the worker, stress both the strong and weak points of his work. Praise work that has been performed skillfully, but do not tolerate sloppy work. Avoid criticism, sarcasm, or personal references, since these comments may cut more deeply than you realize and leave the worker with a strong feeling of dislike for you. In brief, don't just use words. Demonstrate correct procedures and give the man the opportunity to correct his faults.

There is one other thing you should do. Check job progression! Don't wait until the job is finished. A job sometimes has to be redone if an error enters the picture before the job is fully completed. This means that failure to check job progression may cause a loss of time as well as of work output. It can, also, lead to harsh feelings and loss of ambition on the part of the man who finds his efforts wasted because he has been forced to do the same job over.

Exercises (629):

1. Tell how the supervisor should review the work accomplished by his workers.

2. *Situation:* As the supervisor arrives at the aircraft, the last unit has been installed. It is being readied for an operational check. He watches the operational check being accomplished and sees that the system works. He then directs the workers to ready the aircraft for flight. Identify the error, if any, that this supervisor has committed.

630. Provide the reasons and procedures for establishing work methods, controls, and performance standards and a desirable side effect and, given a hypothetical situation, indicate what the supervisor is *not* doing that should be done.

Now we turn to the setting up of work methods, controls, and performance standards—our subject in this section.

Establishing Work Methods, Controls, and Performance Standards. It is basic that a supervisor must see that his people really accomplish their tasks. Accordingly, in order to insure that his personnel actually meet their objectives, he must set up standards for them. Here he should develop standards that can be met by *most* of his assigned personnel. To judge established work methods, he devises standards. For example, the supervisor requires the use of a checklist and/or a technical order for each task. Even for the simplest task, he checks to see that his people have the needed technical data. Such factors as the care and handling of test equipment, the cleaning of the shop areas, and dress and grooming standards should be controlled by the supervisor. Then, during his daily activities, he should survey his area to make sure that his people are meeting these standards.

Obviously, though, the mere establishing of a work method or performance standard is not a cure-all for careless or unsafe workmanship. Once this and other standards have been established, the supervisor must then control all of them to insure that they are being met and that they remain consistent with the current shop workload. If he discovers that an area is falling below standard, he should set up a program to get it back to the standard quickly. Hold it! Did you notice that we used the word "quickly," just now? This is very important to every supervisor. Why? Because if he lets something slip for "just awhile" because he has other things to worry about, the observable substandard condition may appear to some to *be* the standard. All right, one way of a supervisor's maintaining control of methods and standards is for him to assign subordinate supervisors the responsibility of helping to determine when areas or methods are falling below standard.

An important benefit of your, like other supervisors, having clearly defined and controlled work methods and job standards is that these will enhance the morale of the people working for you. After all, most people are more interested in their work when they know exactly what is expected of them as far as the quality of work they produce and the procedures they use to complete the work are concerned.

Exercises (630):

1. The supervisor establishes the work methods. Tell what else he must establish to control the operation of his shop, clarifying the importance of this other step.

2. Provide the reason for a supervisor's correcting a person as soon as he notices that he needs a haircut.

3. *Situation:* A supervisor had established good work methods and performance standards when he took charge of a certain shop. However, after a while, the quality of the work produced and even the appearance of the shop has began to become substandard. Indicate what the supervisor is failing to do.

4. State a desirable side effect of controlled, well-established work methods and job standards.

631. Concerning using performance reports to evaluate worker performance, tell the purpose of such reports, why—except for the annual requirement—they are prepared, the comments to enter on one, the publication with guidelines on its preparation, and why a supervisor should prepare one before the CBPO notifies his unit.

Supervision is impossible without performance reports, which is this BOF segment's subject.

Performance Reports. As a supervisor, you must judge people every day as you come into contact with them. You find that some people are outstanding; others, just normal, "every-day" type people. Also, you may find a few who can be termed as "undesirables." You should keep these judgments in your mind for later. Why? Because you will have to write an Airman Performance Report (APR) on each of these people. Every enlisted person in the Air Force receives at least one APR a year. Of course, a few other times come up when APRs are submitted, such as the change of reporting official (CRO) and the removal of a man from a control roster, etc.

Airman Performance Reports are used to select the best airman for promotion. The problem is, as you should understand, that not everyone assigned to your section can be promoted just as soon as he gets time in grade. On the APR form, AF Form 909, Airman Performance Report, under the title of Personal Qualities, you will find six areas on which to rate the airman. These areas are titled:

1. Performance of Duty.
2. Working Relations.
3. Learning Ability.
4. Self-Improvement Efforts.
5. Adaptability to Military Life.
6. Bearing and Behavior.

There is, also, an overall evaluation section, where you rate the worker, again from zero to nine. Specific comments are required of you to justify either extremely high or extremely low ratings. Thus, for example, in order to get outstanding workers promoted before their average coworkers, you must write specific comments which reflect their outstanding qualities. Now as you are aware, you should try to rate your workers as fairly as possible. This is not easy to do. In fact, it is people who are *average* who are the hardest for you to rate fairly. But your comparing them against other airmen of the same skill level, job knowledge, and rank may help you here. Don't forget, also, the other two forms for rating others of higher grade: the AF Form 910, TSgt, SSgt, and Sgt Performance Report; and AF Form 911, CMSgt, SMSgt, and MSgt Performance Report. Each of these ratings depends largely upon job knowledge, supervision, training, and acceptance of responsibilities.

You have available to you specific guidelines for accomplishing the various types of performance reports. Use them. Why? Because if you do *not* follow these guidelines, either (1) your report will not be accepted, in which case you will have to reaccomplish it, or (2) the report will not have the effect that you have intended for it to have. Either way the ratee will suffer—due either to the lateness of the report or inaccurate data. You can avoid all of this when you must write a performance report, even if you have already written several of them. How? Simply by your always reviewing carefully AFM 39-62, *Noncommissioned Officer and Airman Performance Reports*, which gives guidelines for completing each block on AF Forms 909, 910, and 911.

Normally, the base personnel office will notify the shop supervisor through the unit orderly room well in advance of the date that a performance report is due. However, a good supervisor will not rely on that notification. Instead, he will see that a list is made of all of the personnel under him. For each individual on this list, both the date of the last APR and the date the next one must be given. In this way, the supervisor can insure that he has plenty of time to get the APR written. Still, note that an accurate and well written APR cannot be accomplished in a couple of hours. Each report requires much thought, research, and personal observation. Also, the supervisor's list should include notes about the various schools, ECI courses, and other educational advancements that each ratee has participated in *during* the period of the report. These items can be listed in the specific comments section of the performance reports.

Exercises (631):

1. Give the purpose of performance reports.

2. State the reasons, other than the annual requirement, that you should prepare a performance report on an individual.

3. *Situation:* You have rated a person on AF Form 909 and have given him a 7 in one area, a 5 in another, and 6s in the rest of the areas, including the overall block. Indicate whether or not you are required to make comments on the report.

4. Identify the publication you should refer to when writing a performance report.

5. Point out why a supervisor should not wait to prepare for APRs until CBPO sends notification that a performance report is due on one of his/her subordinates.

632. State the reason for the USAF Graduate Evaluation Program, the evaluation methods employed, the use and care needed for the direct correspondence questionnaire, and the conditions requiring submission of an AF Form 1284.

All Air Force formal training courses are constantly undergoing changes as a result of changes in equipment, procedures, or needs of the Air Force Occupational Surveys and changes in the USAF Graduate Evaluation Program, which we will discuss next.

Reasons for Program. The graduate evaluation program is a major aid in the quality control of formal and career development courses. The program is a source of information used in determining the following:

- Ability of recent graduates to perform their assigned tasks to the proficiency level specified in the applicable training standard.
- Extent to which acquired skills are used by recent graduates.
- Extent to which acquired knowledge is retained by recent graduates.
- Need to revise the approved Specialty Training Standard, formal courses, or Career Development Course in order to improve training effectiveness and responsiveness to the requirements of the using commands.

Evaluations and Reports. The evaluation of graduates can be conducted in any one of these four ways: (1) field evaluation visits, (2) direct correspondance questionnaires, (3) job performance evaluations, or (4) the CDC trainee questionnaire.

Field evaluation visits. Training activities are authorized direct communication with the organization to be visited in order to arrange for the visits. The personnel from the training activities are concerned with the graduates assigned to the unit within 6 months immediately before the visit. Evaluation data is obtained by actual discussions with the graduate, the immediate supervisor, and others having knowledge of the graduate's performance. The applicable training standard is used as the reference to evaluate the graduate's frequency of use and their ability to perform the tasks for which trained.

Direct correspondence questionnaire. The questionnaires for formal course graduates are sent to recent graduates and their supervisors. They are mailed by the training activities to graduate-receiving units within 6 months after graduation (within 24 months for personnel not on extended active duty and who are assigned to USAFR and ANG units). The questions asked pertain to graduate qualification in terms of the skills and proficiency levels reflected in the approved training standard. IT IS EXTREMELY IMPORTANT THAT THE ANSWER SHEETS BE HANDLED CAREFULLY. Why? Because staple holes, frayed corners, paper clip impressions, extraneous pencil marks, creases, and light pencil responses will cause the scanner to reject the answer sheets.

When a sufficient number of responses have been received by the originator, a Training Evaluation Report is prepared by the Evaluation Division (TTE) of the technical training center concerned. This report is an in-depth study of the information supplied relative to the supervisor, the graduate, and the additional personal comments of the supervisors in regard to suggested improvements. The results of this report are immediately responded to by course personnel, resulting in the change(s) necessary to adapt that training to total AF needs.

Unfortunately, it is not economically feasible to train everyone to perform all job tasks encountered in all job assignments. Formal training time must be slanted toward satisfying the common needs Air Force-wide. Those additional job performance requirements that are peculiar to an individual's job assignment must be acquired through on-the-job training (OJT).

CDC Trainee Questionnaire (AF Form 1327). The CDC Trainee Questionnaire is completed by a sampling of the CDC enrollees when they take course examinations. The CDC testing officials collect the forms and mail them to ATC training centers within 1 week of administration of the test.

At the training centers, the AF Forms 1327 are analyzed in much the same way as are the formal course graduate direct correspondence questionnaires, and the results are the same. If responses to AF Form 1327 identify problem areas in the CDC, the training activities will conduct followup evaluation projects to determine the actions required to resolve them.

There appears to be some apprehension in field-level units that CDCs do not contain specific equipment maintenance-related job procedures. This is in full accord with the AF dual-channel OJT concept. Career Development Courses are designed to provide the learning material. OJT utilizes these knowledges while allowing the individual to be a productive member of the AF team and/or learn more advanced or new skills or to develop higher proficiency levels in those skills previously acquired. Every individual working on the job should realize that he has a responsibility to train lower-level personnel and increase his productivity in AF-assigned job tasks.

Job performance evaluation. Because of the time and expense involved in this method, it is rarely used. However, if the required training evaluation cannot be obtained by less costly means, a job performance evaluation is conducted as follows:

- Technical Training Center personnel visit the organization to which the graduate of interest is assigned. A checklist of tasks that require evaluation is coordinated with the graduate's supervisor.
- The supervisor evaluates each of these tasks as it is completed by the graduate. When all tasks have been evaluated, the resuts are mailed to the Technical Training Center.
- Technical Training Center personnel follow up the evaluation by phone or another visit.

Training Quality Report (TQR). This report, AF Form 1284, is used by supervisors throughout all commands to report undertraining or overtraining on any item listed in the Specialty Training Standard (STS).

The immediate supervisor must submit a TQR when he observes that a graduate from a technical training course does not meet the proficiency level specified for a task or knowledge listed in the approved STS. Also, he must prepare a TQR if the graduate is not required to perform tasks listed in the STS for the AFS in which the graduate is assigned. A TQR is also required when the STS code levels of tasks exceed the requirements of the AFS.

Exercises (632):

1. Provide the reason for the USAF Graduate Evaluation Program.

2. List the four evaluation methods used in the graduate evaluation program.

3. Give the use of the direct correcpondence questionnaire and the reason for handling the answer sheets carefully.

4. Indicate the two conditions which require the supervisor to submit an AF Form 1284, Training Quality Report.

633. Clarify the methods and procedures used to resolve technical and individual problems met by subordinates, points to remember when reporting a worker's progress to him, and methods to make sure individuals are used to the utmost.

Machinist-supervisors also must resolve technical and individual problems. These concern us here.

Resolving Technical Problems. As a supervisor, you will be called upon many times to solve technical problems. "Ask the boss," is the standard answer when anyone encounters a problem. Well, when you are that *boss*, you must come up with the answers. The answers you give will go a long way toward establishing your reputation as a supervisor. Therefore, you must come up with a good answer. Perhaps your past experience will be of use to you in the form of so-called "tricks of the trade." Or perhaps you will have to research TOs or manuals for the answer. Maybe your just telling the worker with the problem where to go to find the answer will suffice. Again, it may be that you will have to ask for outside help, if the problem is beyond your knowledge or ability to solve. In any event, never leave a problem unsolved if it is at all possible for you to solve it. Remember, too, that if you refer one of your people to someone else for a solution to a problem, you should check back with him later to see whether or not he has found his answer. Why? Because by doing this, your people will get the feeling that *their* problems are *your* problems, too—which they are. This situation will increase the worker's confidence in you as a supervisor.

Resolving Individual Problems. Much has been written about how to get along better with other people. Considerable emphasis has been placed in base-level management training programs on the why and how of working with people in a team spirit to reach a common goal. Now let us review the subject of employee relations and study procedures to apply in handling a discussion.

Employee relations. Instead of a long discussion on the factors concerning employee relations, let's just list the normal foundations necessary for good employee relations, then present an outline of an effective procedure for handling their problems. The following items will aid you with many employee relations problems. No they are not all-inclusive, but they will give you a start in the right direction. As you observe other supervisors at work and gain experience, you can add to this list:

a. Let each worker know how he is getting along. To do this:
- Tell him what you expect of him.
- Point out ways he can improve his work.
- Praise him in public and criticize him in private.

b. Give the worker credit where credit is due. Here you should:
- Look for extra or *beyond the call of duty* performance.
- Tell him *now*, while it is *hot*.

c. Inform people in advance about changes that will affect them. This means to:
- Tell them why this has happened, if you know.
- Sell them on the idea of accepting the change.

d. Make the best use of each person's ability. Accordingly, you need to:
- Look for that *extra* ability that may not be in use.
- Never stand in an individual's way as he seeks to develop his abilities.

Handling a problem. One of your responsibilities—with which you may have trouble at times—is handling a problem encountered by one of your subordinates. There is always the chance you may be confronted with difficult situations which appear to have no solution. There are, fortunately, tried and proven procedures which you can use to help solve most problems. A procedure or approach you can apply in a difficult situation is as follows:

a. Get the facts. To do this:
- Review the record.
- Find out what rules and regulations apply.
- Talk with the individual concerned.
- Get his opinion and feelings.
- Be sure that you have the complete story.

b. Weigh and decide. Here you should:
- Fit all of the facts together.
- Consider their bearing on each other.
- Answer this question: What different, possible courses of action are there?
- Check practices and policies of your organization at your level.
- Consider objectively the effect on the individual, group, and work.
- Don't jump to conclusions.

c. Take action. This means asking these questions, then acting as shown:
- Will I handle this myself?
- Will I require help from others?
- Should I refer this problem to my supervisor?
- Make your decision and time your actions to fit the decision.
- Don't pass the buck.

d. Check the results. Here, ask these questions, then act as shown:
- How soon will I follow up?
- How often will I need to check?
- Observe changes in output, relationships, and attitudes.
- Has my action increased or decreased the work output of the individual or group involved?

Exercises (633):

1. *Situation:* Suppose one of your people encounters a technical problem that he cannot solve. Indicate where he normally should go for assistance.

2. *Situation:* Suppose you are given a technical problem by one of your people that you cannot answer. Relate your next step.

3. *Situation:* Suppose you refer one of your people to someone outside of your organization for assistance on a problem. State the reason you should check to see that he gets a satisfactory solution.

4. Give some points to remember when you are telling a worker how he is progressing.

5. List two methods to insure that you are using a person to the best of his ability.

6. Identify the procedures you should apply when problem-solving.

7. *Situation:* Suppose you are making a plan to check the results of a job. Cite some things you should ask yourself at this time.

634. Concerning organizational and functional charts, identify areas of responsibility on an organizational chart, indicate the position of the shop supervisor, and state the purpose of a functional chart.

What is the use and what are the contents of organizational and functional charts you need to know. This segment answers these questions.

Assigning Positions Using Organizational and Functional Charts. As you become a supervisor, you will find that you cannot oversee every area of responsibility truly efficiently, because of time, distance, etc. factors limiting you. To ease some of your workload, you may begin assigning certain areas of responsibilities to your subordinates. But remember, although you may assign tasks to others, *you retain the responsibility*. That is, as you assign these tasks, *you delegate authority* to accomplish the task. Among duties often assigned to subordinates are: (1) on-the-job trainer, (2) equipment manager, (3) shift supervisor, (4) safety supervisor, (5) team chief, and (6) assistant shop supervisor.

By developing an *organizational chart*, you can show a picture of your organization. In other words, you can depict who is responsible to whom and how the lines of authority run within your shop. To this end, an organizational chart normally shows *one* level of supervision *above* and *two* levels *below* the charted position. Thus, as shop supervisor, your chart would show your position as the *main* position. One level above you would show your supervisor. Below your position would appear your assistant supervisors, while below them, perhaps, would be the team chiefs. Of course, the actual positions you enter on the chart will depend upon the positions you have assigned within your own shop.

A *functional chart* will appear much like the organizational chart, except that the duties and responsibilities of each position will be listed on the chart. It may also list job descriptions and AF publications required to accomplish the assigned tasks. Therefore, the functional chart serves as a quick reference as to which responsibilities a specific position carries with it.

Exercises (634):

1. Provide the areas of responsibilities that a supervisor may want to show on an organizational chart.

2. Tell how, when making an organizational chart, you should position the shop supervisor.

3. State the purpose of a functional chart and the information listed on it.

635. List conditions that may affect manning and equipment authorizations, identify selected actions used to justify a commander's problem resolution, and give a commander's reason(s) for wanting to review manning and equipment information.

Personnel and equipment must be justified. How? This BOF unit will discuss this topic.

Justification of Personnel and Equipment. Justification of personnel and equipment is certainly an important part of a supervisor's responsibilities. You already know that to accomplish the mission you must have the necessary equipment and manpower. In today's Air Force, aircraft systems are being modified every day. Some systems may be removed, improved, or replaced with a complete new system. This may effect your manning and required maintenance equipment. Overtime necessary to support the mission may indicate undermanning or lack of training. Thus, many areas exist which you must look at very closely when you justify personnel. To being with, look at the unit's mission. Ask yourself these questions: Have the temporary duty (TDY) assignments been compiled correctly? Are you accomplishing tasks normally assigned to other sections? Has the wing been assigned additional flying hours? Has transit aircraft traffic increased? One final question: Are these going to be temporary or permanent conditions? Also, check the unit detail listing (UDL) to see how many men are authorized. Remember, the UDL may authorize more people than are assigned at the present time. In any event, if you determine that the mission cannot be supported properly, alert the commander to the problem.

Before personnel and equipment can be justified, it is important to have all necessary information. Accordingly, the commander normally keeps close watch over his manning and equipment authorization. It is possible, however, that you may supply one small fact that may serve as justification for an emergency manpower request or reassignment of work to other sections. The same is true of equipment. Replacement for faulty equipment or that which is in limited supply and hard to repair may be justified. This is why the commander may want to review the facts with you; he wants to insure that he *does* have all of the necessary information clearly in his mind before going to higher commands for help.

Exercises (635):

1. List those conditions that may affect manning and equipment authorization.

2. When a manpower problem is given to the commander, he may use two types of action to solve the immediate problem. List these actions.

3. Tell why the commander wants to review manning and equipment information.

3-2. Conducting Training Programs

An organization capable of doing its job must conduct an endless and effective training program. Every time a piece of equipment is developed, men have to be trained to operate and maintain it. This training is needed if we are to get the greatest use and performance from our equipment. Commanders, personnel officers, training officials, and supervisors must see that this training is conducted as efficiently and as effectively as possible.

Most of the training in the Air Force is conducted on the job. On-the-job training (OJT) is not new. It was used by the cavemen when he taught his sons how to hunt, trap, and make crude weapons. It was used in Europe hundreds of years ago in the craft guild system. It has been used in industry in this country for many years. Today, most companies have well-organized and effective training programs. OJT is a system that works. Obviously, poorly trained workers mean an increase in waste. They also can cause damage to equipment, inefficient operation, lower production, and lower profits. In contrast, well-trained workers mean higher production, good morale, greater profits, and higher wages. Remember, if industry does not train its workers, it loses money; if it loses money, it goes out of business. But the USAF cannot afford to go out of business; so it conducts a training program to keep its personnel qualified to perform all of their duties and functions. This training is necessary if we are to have an efficient, well-manned Air Force capable of carrying out its assigned mission.

636. Give the requirements of an effective OJT program, reasons for setting up this program, the meaning of dual-channel concept, and the document controlling CDC content and the role of CDCs in UGT; explain QT briefly; and given an OJT situation, tell why the supervisor failed.

As a machinist-supervisor, you need to understand On-the-Job (OJT) training thoroughly, because you will be dealing with it. This is our subject here.

The OJT Program. To be effective, an OJT program requires detailed planning, careful scheduling, timely implementation, capable direction, skillful application, and continuous evaluation.

The gains from OJT in Air Force operations are numerous. With a better trained staff, the supervisor has more time to look and plan ahead and to focus on the improvement of present work methods and conditions. He has more relief from details and less worry and nervous strain; he can develop himself as a leader. The worker also benefits from OJT, because he has more opportunities for special training. This training will also help him become more useful to his unit, because he develops a sense of responsibility and a better understanding of his job and learns the value of systematic work habits. OJT may be conducted for either of two reasons: (1) upgrade training (UGT) or (2) qualification training (QT).

UGT through OJT. OJT is a planned training program. It is designed to qualify airmen, through self-study and supervised instruction. It also qualified them to perform in an Air Force specialty (AFS) while actually working in a duty assignment of the AFS. The new OJT program consists of two parts: (1) job knowledge and (2) job proficiency development. This is known as the *dual-channel OJT concept.* Satisfactory completion of each part is necessary for eligibility and selection for upgrading.

The fundamental knowledge required for upgrade training (UGT) is contained in the Career Development Courses (CDCs). CDCs are published and administered by the Air University's Extension Course Institute (ECI). ECI is responsible for the airman's initial enrollment. They also score the end-of-volume examinations, maintain student records, and issue certificates to all enrollees who satisfactorily complete the course.

The Specialty Knowledge Test (SKT) has been removed from the skill upgrading system for the 5 level. The SKT results are now used as one of the factors in computing an airman's score in the new Weighted Airman Promotion System (WAPS). The 3 skill level SKTs will continue to be used for both upgrading and identifying bypassed specialists. The information to answer the questions correctly in an SKT for a particular AFSC can be found in the references listed in attachment 2 of the appropriate STS. When a CDC is available, it is used as a major source of SKT information. However, the study reference list may also contain references other than the CDC to insure complete and current coverage.

CDCs contain information on career field basic principles and the common job knowledge requirements in each specialty. The subject matter is based on the knowledge elements listed in the approved USAF Specialty Training Standard for the specialty. The extent of training is determined by the code level shown in the STS. STSs are discussed in more detail in a later section. Each CDC is self-contained, and outside reading is not necessary to complete it.

The job proficiency development portion is accomplished through the use of Job Proficiency Guides (JPGs). The primary purpose of the JPG is to provide the airman with a reference for each task he must perform. Job Proficiency Guides have these four essential elements: (1) a list of tasks for the AFS, (2) required proficiency levels for all tasks, (3) study references of Air Force and other publications for each task assigned, and (4) space for the supervisor's certification when the prescribed proficiency level has been attained.

QT through OJT. Qualification training is different from upgrade training in that, in taking such training, the trainee is not preparing for a higher skill level. Instead, in QT, the trainee is trained on a specific task that he/she may not have performed before. For example, Airman Smart is a fully qualified 5-level specialist, but when he arrives at a new base, he finds that he will be required to bench check and repair power takeoff couplings from assigned aircraft. The problem is that he has never even seen such a coupling before and naturally does not know the procedures involved. Fortunately, his supervisor realizes this; so he enters Airman Smart in qualification training to teach him how to properly accomplish the task. There is no specified time limit for QT, nor is there a CDC involved. The supervisor determines when Airman Smart can successfully accomplish the job on his own and then signs the appropriate OJT forms certifying that he is qualified. This removes him from QT. It is to the trainee's advantage to make official entries in his OJT records when he is placed in QT, since he can show his next supervisor the areas in which he is qualified to perform work.

Exercises (636):

1. State the requirements of an effective OJT program.

2. *Situation:* A supervisor finds that he is always behind in his work, because he must spend much of his time showing his subordinates how to do their assigned tasks. Indicate the most likely cause for this.

3. Idenfity two reasons for establishing an OJT program.

4. Define *dual-channel concept.*

5. Name the document controlling the content of CDCs.

6. Specify the part the CDC plays in UGT.

7. Explain briefly "qualification training" (QT).

637. State why and when OJT is needed and where it is conducted and, given a hypothetical situation, identify the OJT-type training involved.

Concerning OJT, why, when, and where is it required and conducted? This portion of this text discusses these things.

Why OJT Is Needed. Air Force jobs require various combinations and degrees of skill and knowledge. Some are highly complex and require lengthy training periods; others are less complex and require less training. Most of the training for the less complex jobs is conducted through on-the-job upgrade training programs, which include self-study and proficiency training. For the more complex jobs, primary consideration must be given to the knowledge requirements. Since knowledge is easily acquired in the classroom, it follows that most airmen who are selected for training into such jobs receive their first training in technical schools. After an airman has received the appropriate training in a formal school or on the job, however, he still has to become proficient in a duty position of the AFS. An airman may become a semiskilled machinist as a result of formal training, qualifying score on the bypass specialist test, or OJT. But he must receive training on the job to become a fully skilled worker. OJT is necessary because formal schools cannot effectively teach one of the most important ingredients needed to become a skilled machinist. That ingredient is job experience.

When OJT Is Required. These are specific instances when OJT is required of an individual. For example, each unskilled basic airman who is given a directed duty assignment (DDA), upon reaching his organization, is entered into OJT for the semiskilled 3-level AFS. This action is indicated on his Uniform Military Personnel Record.

The purpose of OJT from the 3- to the 5-level AFS is to improve job performance. It also increases skills in the machine shop beyond the levels acquired in formal schools. All 3-level airmen are entered into OJT to the 5 level skill, provided that a training capability exists. Semiskilled airmen who do not have the ability to progress will be considered for retraining. They will be retrained into a skill in which career progression is reasonably assured. This is based on aptitudes and prior experience; otherwise, separation action should be considered.

Training from the 5-level to the 7-level skill will be entirely through OJT. The 3-level airmen in pay grade E-5 in career ladders that have no 5-level AFS may be entered into upgrade training for the award of the 7-level AFS. Such training will be given only when training capabilities exist however. Upgrade training of airmen in grade E-5 to the 7-level specialty is permissive. Only those airmen potentially capable of continued advancement should be entered into training.

On-the-job retraining is the training of an airman from his career field or career field ladder into another career field or ladder. On-the-job retraining also includes training an airman for a different suffix to his AFS. An example is an aircraft mechanic, AFS 43151C (jet aircraft, one and two engines) retraining to AFSC 43151E (jet aircraft, over two engines).

In some AFSs, normal progression involves a change of career field or career field ladder. This is termed "lateral training." For instance, an airman assigned to the tabulating equipment repair ladder, AFSC 401X1, must hold AFSC 40150, because the only authorized input is from this source. Lateral training may be given either through formal courses conducted by the Air Force or through OJT conducted at the unit level.

Another type of OJT is proficiency training. This is designed to enable the airmen to acquire more detailed knowledge and to attain greater skill within this assigned position. Closely related to proficiency training is qualification training. As we have stated in an earlier objective, qualification training is conducted for individuals who have already been upgraded but who need training in an area not previously required.

Where OJT Is Conducted. The entire OJT program hinges upon the learn-by-doing and self-study concepts. As we have said earlier, job proficiency training normally is conducted within the unit to which you are assigned. This is accomplished through self-study courses. The responsibility for conducting the job proficiency phase of OJT rests with every person who supervises your work. However, the knowledge development phase of OJT through self-study courses rests with you, the trainee.

Learning in a job proficiency situation normally occurs as a result of the close relation and understanding between the trainee and the trainer. You should understand, though, that this coach-pupil method of training does not prevent short periods of group instruction. Such instruction is, after all, sometimes the most practical way for presenting essential theory.

Exercises (637):

1. State the reason OJT is needed.

2. Tell when OJT would be required to train an airman to a 3-skill level rating.

3. Clarify the circumstances in which a 3-skill level airman could be entered into 7 skill level training.

4. *Situation:* Sgt Alpha was awarded his 5 skill level rating several months ago. However, a change in the shop mission will now require him to be trained to operate a new and complicated jig-bore-grinder. Indicate the type of training this would be documented as.

5. Relate where OJT is conducted.

638. Give the specific duties and responsibilities of all key personnel and units in an OJT program and identify the publication providing each position's responsibilities in a base OJT program.

Who or what units have what OJT duties and responsibilities? Since, as a supervisor, you will need to know these things, they are the subjects of this BOF unit.

Duties and Responsibilities for OJT. The logical first step in planning an OJT program is to outline the responsibilities involved. This is the basis for setting specific duties at each level. It also identifies the individuals who perform such duties. In the following paragraphs, we will discuss the duties and responsibilities of OJT at various levels of command.

Commander. Commanders at all echelons must accept final authority for all activities which they command. OJT is an inherent responsibility of command at all echelons. The commander who insists on a bonafide OJT program is taking an important step. He does this by insuring the continued accomplishment of both his unit's mission and the total Air Force mission.

OJT will not operate under its own momentum, however. Indeed, to produce the desired results, an OJT program must have the positive support of the commander. Why? Because a positive attitude generated at the command level builds enthusiasm at the lower echelons. This better enthusiasm insures the ultimate success of the program.

Thus, commanders at all levels are responsible to insure that qualified personnel are assigned to properly administer and supervise OJT programs. In addition, they must insure that OJT programs are properly recorded and that they are effective. Furthermore, they must insure that OJT programs are conducted free from discrimination with regard to an individual's color, race, religion, age, or sex.

Servicing Consolidated Base Personnel Office OJT monitor. The individual involved here is the NCOIC of the CBPO-OJT unit. He/she is responsible for staff supervision and monitoring of all the OJT programs within the units serviced by the CBPO. This individual must plan, organize, and direct the overall OJT program, insuring that equal service is rendered to all units (host and tenant) for which he/she is responsible. Also, this individual and the associated staff must validate and forward mandatory CDC applications to ECI. He/she is responsible for administering CDC course examinations, maintaining records of current UGT statistics, coordinating all applicable training forms, preparing higher-headquarters directed reports, and advising commanders and squadron training administrators on setting up effective OJT programs. Still more duties and responsibilities are listed in AFM 50-23, *On-the-Job Training,* but just these will give you a good idea of the extent of the CBPO-OJT monitor's job.

Squadron OJT administrator. At the squadron level, the responsibility for planning and organizing the OJT program should be assigned to an individual who has experience in personnel actions, training programs, and the specialty most closely representing the squadron mission.

The responsibilities of the squadron OJT administrator are too numerous to list all of them here. Therefore, for a complete list, you should consult AFM 50-23. Some of the more outstanding responsibilities may be given, though. They include advising the officer-in-charge and supervisors on the concepts, scope, and objectives of OJT; enrolling trainees in appropriate CDCs and forwarding applications to the CBPO-OJT unit; coordinating training forms between supervisors and CBPO-OJT unit; and making regular 90-day visits to sections within the squadron to check on training effectiveness and documentation. In addition , he/she must assure the accuracy of the various training request forms and must prepare AF Form 623 on trainees and deliver them to the supervisor. Furthermore, he/she receives and distributes ECI materials to the immediate supervisor for personnel enrolled in CDCs, except for Volume Review Exercise (VRE) answer sheets—which are retained at the squadron OJT unit—and administers VRE tests after assuring that all BOEs for the appropriate volume have been completed.

Immediate supervisor. Responsibility for conducting OJT is inherent in the position of all supervisors. Thus, the supervisor occupies a key position in the OJT program, since he or she daily contacts all personnel assigned to his unit. In smaller sections, the immediate supervisor may also be the trainer. The term "immediate supervisor" is applicable to that person who maintains OJT records and forms and who is responsible for those duties and responsibilities listed for him/her in AFM 50-23. The immediate supervisor's responsibilities include selecting qualified trainers from the section; developing job proficiency guide (JPG) for trainees; certifying proficiency training by initialing the JPG; counseling trainees when problems arise; maintaining AF Forms 623 for assigned airmen; and initiating AF Form 2096 to enter, complete, or withdraw from training. In addition, the immediate supervisor must conduct initial evaluation for newly assigned personnel, hold the CDC package and issue the trainee one volume at a time, and monitor CDC progression and provide assistance as necessary.

OJT trainer. Ideally, the OJT trainer should be the trainee's immediate supervisor. This, however, cannot always be arranged, and the trainer must then be appointed by the immediate supervisor. The trainer's responsibilities are to prepare detailed task breakdowns for the trainee, instruct trainees on actual equipment, teach theory and background information, and motivate and evaluate assigned trainees.

When you have the opportunity to be an OJT trainer, you will find that motivating trainees will easily be your hardest task. Knowing this, it may help you, too, to know that it is surprising what can be accomplished when you treat each trainee as an intelligent individual. Too many trainers treat the people they are training as illiterate simply because the trainees don't know as much about the job as the trainer does! The trainer should always remember that he had to be trained by someone, too, and try to look at the trainee's difficulties from the trainee's point of view. Another thing that will help to motivate trainees is to give them meaningful jobs when possible and don't just give them all the dirty or undesirable jobs.

Exercises (638):

1. State who, within a squadron, is charged with the overall responsibility for OJT.

2. Indicate who must insure that only qualified personnel are assigned to properly administer and supervise OJT programs.

3. Give the responsibilities of the CBPO-OJT unit concerning mandatory CDCs.

4. Reveal the person charged with the responsibility for testing trainees on volume review exercises.

5. Tell who, within a unit, initiates AF Forms 623 on individuals.

6. Identify the publication that lists the responsibilities of each position within a base OJT program.

7. The responsibility for conducting OJT rests with ________________ .

8. Cite the conditions in which the immediate supervisor would be responsible for preparing detailed task breakdowns for the trainee.

9. Relate how, as an OJT trainer, you can help to motivate trainees.

639. Clarify the steps, procedures, and methods in and results of administering and conducting OJT and, given hypothetical situations, identify the training techniques violated in each.

You, as a supervisor, will be involved inevitably in the administering and conducting of OJT; so these are the subjects of this BOF segment.

Administering OJT. Obviously, effective OJT programs never result from chance. They are planned. They then remain effective only as a result of proper administration and supervision.

The selection of personnel to meet the manpower needs begins at the indoctrination center, where scientific methods are used to discover individual abilities and aptitudes. That is, proficiency and/or advancement tests are employed to measure the individual's knowledge and skills in specific fields. Likewise, aptitude tests are utilized to discover and measure potential traits in persons who have had little work experience in a specific field. These measurements are used to predict the abilities of the individuals involved. The objective is to place each airman in a specific career field for which he/she shows aptitude. Consequently, his/her potentialities can become a reality through the technical training program and the work experience provided by the Air Force.

Status of training. Once the OJT program of a unit has been planned, organized, and scheduled, it is important for the supervisor to be constantly aware of its actual status. This makes it possible to measure a unit's progress toward meeting the program's intended objectives. It will indicate the inadequacies in the OJT program in sufficient time to make necessary adjustments.

Personnel actions. All personnel who administer or supervise OJT programs, such as you when you supervise must have a thorough understanding of the procedures, especially those pertaining to entering airmen into or removing them from job training status. These individuals must be able to apply their knowledge of OJT procedures to the local situation.

Conducting OJT. In some ways, instructing is no different from other work. For instance, you either like it or you don't. If you do not like to instruct, you likely cannot do it successfully. But teaching is an essential part of the supervisor's and trainer's job, and the person who cannot instruct successfully is not a truly effective supervisor or trainer.

Good instruction produces two very desirable results. *First,* your trainees become more competent and so can do better work. *Second,* you have the personal satisfaction of knowing that, through your efforts, each trainee has become a productive worker.

Training principles. Because certain principles apply to training situations, supervisors should conduct local training programs to qualify on-the-job trainers in the use of these basic principles. Accordingly, trainers should understand and apply the following principles in order to improve their skills in instruction:

a. Go from the known to the unknown. Find out what the trainee already knows and compare your subject with something he already knows. Give him a complete and friendly briefing on the overall program and where he fits into it. Acquaint him with his goal, making sure that he understands his part in the organization and that he is a member of the team.

b. Go from the easy to the difficult. Always begin with the simple parts of a job. If he learns, after a short practice, that he is able to perform parts of the job, the trainee will gain confidence and be better inspired to learn the whole job.

c. Emphasize accuracy and understanding, rather than speed, while the trainee is learning.

d. Emphasize safety at all times.

e. Clearly define the limits of the training objectives, letting the trainee know what is expected of him.

f. Present new material in short units—units that he can finish in one training session. Short, related training units are not so likely to confuse him.

g. Be sure that the trainee sees the job as a whole. This means to fit all of the short steps into the whole operation or objective.

h. Always remember that the trainee learns by doing. So put him to work just as soon as he understands what he is to do, giving him plenty of practice.

i. Allow the trainee to develop by himself. Remember, *He* does the learning; you merely guide and help him. Consequently, be careful not to dominate, even though you should not relax your supervision to the extent that the trainee can harm himself and others or damage equipment.

j. Make sure every training procedure you use makes sense to the trainee. If it doesn't do this, change or discard it.

k. Never try to bluff.

l. Never resort to sarcasm and/or ridicule.

Training methods. If you are chosen to be an OJT trainer, you will be required to meet your responsibilities as trainer in addition to your other duties. The reason for this is that the job of trainer is not intended to be a full-time duty. Obviously, as an OJT trainer, you are neither required nor expected to become a professionally qualified educator. Still, you *are* expected to use certain effective training methods and techniques. Therefore, when you are selected as a trainer, you must learn to perform efficiently, using those methods that produce an OJT program. Job instruction generally involves these four methods of imparting new knowledge or manual skills: (1) lecturing, (2) discussing, (3) demonstrating, and (4) performing.

a. The lecture method. This is a useful method of imparting information. Its effectiveness is increased, however, when it is combined with one or more of the other instructional methods. Also, used alone—when the training objective is the development of new manual skills, such as operating the subsystem tie in a test set—the lecture or telling method has limited value.

b. The discussion method. This, too, is a valuable training method, because it promotes a two-way exchange of ideas during group instruction. This method is definitely effective when the objective is to provide background information on procedures that are of common interest to the entire group. You will find questioning very useful during discussion—both to inform the trainee and to check his grasp of the material. But note, in order to help the trainee think through the logical steps of a new job task, phrase your questions so that they can't be answered with a straight Yes or No. To this end use questions that begin with such words as *what, who, where, when, why* and *how*. Questioning and discussion can be used effectively with all instructional methods.

c. The demonstrating method. Also termed "showing," this is most effective when the training objective involved is the development of manual skills. It is particularly useful when it is employed in presenting the steps of a very long operation—one which must be performed without stopping. The trainee is taught a part of the job, with the trainer doing the rest. After learning one step of the total job, the trainee is taught a second step, with the trainer again completing the operation. In this way, the trainee learns the whole job in small segments. Note that the effectiveness of the demonstration method is increased when it is combined with the discussion method.

d. The performance method. This method is by far the most effective to use in OJT. Under the watchful, experienced eye of the trainer, a trainee truly "learns by doing" while, at the same time, he is performing in a productive capacity. An OJT airman should immediately be given a simple job to do, such as removing modules from an amplifier. It is most practicable to assign the airman-trainee to assist others who are producing. After he has been trained in a specific task or phase of work, he should be permitted to perform that task until he is able to do it with the desired proficiency. Then he should be rotated to another task. With a progressive rotation plan, the trainee grows in skill and knowledge until he is able to accomplish all of the requirements of his duty position effectively.

Training techniques. Clearly, all supervisors must be sure that trainers use training techniques which achieve good results. To this end, study the five techniques discussed in the following paragraphs, using them to develop techniques of your own:

a. Prepare the training situation. This means to:

(1) Be sure that the tools and equipment are on hand and are in good working order.

(2) See that the shop or room is available and that it is properly heated, lighted, and ventilated.

(3) See that the training aids you will use are available and in good working order.

(4) Remember that a large portion of your training time will be spent on the flight line, where you do not have complete control of conditions.

b. Prepare the trainee to receive job instruction. Here you should:

(1) Put the trainee at ease. To do this, work to help him build his confidence. Your training efforts are likely to be in vain if the trainee is nervous or ill at ease.

(2) Find out what the trainee already knows about the job. Don't tell him things he already knows. Instead, start where his knowledge ends.

(3) Gain his interest. Do this by explaining the operation at hand and relating it to the work of the whole unit. This will help him realize the importance of his job.

(4) When you are demonstrating a task, make sure that the trainee observes it from the proper position. That is, never let him look at the job backwards or from any angle other than the one from which he will actually work.

c. Present the operation to the trainee. To do this:

(1) Tell him, show him, illustrate for him, and question him. Then, when he understands, have him do the job.

(2) Give only a few instructions at a time. Understanding is gained more quickly if ideas are presented gradually.

(3) Make the key points clear, because these *make or break* the entire operation. To a large extent, they really do determine the ultimate success or failure of the training.

(4) Use available training aids when and as they help you to put the point across. But never use them just to fill in time. Thus, before using any training aid, be sure that it applies *directly* to the subject and that it *works*.

(5) Be patient; remember that haste makes waste. Accordingly, work for accuracy in the task first; speed later.

(6) *Repeat* the job and explanation as often as necessary.

d. Try out the trainee's performance. Here you need to:

(1) Have the trainee do the job under observation. Then have him do it again and, at the same time, explain to you *what* he is doing and *why*. The reason for this is that he may not realize the importance of the motions he observes and repeats, and his talking about the job will reveal this. After all, if the trainee can't accurately describe what he is doing, he doesn't really grasp it, and he *must* understand what he is doing.

(2) Have the trainee explain the key points. Always correct his errors, but never do this in a way that makes him feel that you are dissatisfied with him.

(3) Continue to have the trainee perform and explain until *you* know that he knows.

e. Follow up. This means to:

(1) Put the trainee on his own, so that he will get the *feel of the job* by doing it by himself. But, at the same time, tell him to whom he should go for help if it is needed and make sure that the designated person understands *his* responsibility.

(2) Check the trainee's work frequently—perhaps every few minutes at the start, then every few hours. As you do this, be on the lookout for incorrect or unnecessary moves, but don't make an issue of them. Yes, you should expect a few mistakes, but if there are none, congratulate the trainee for a job well done.

(3) Get the trainee to look for key points as he progresses. Taper off the coaching until he is able to work under normal supervision.

(4) Be sure that the trainee is adhereing to the approved safety practices. Safety is one of every supervisor's most important responsibilities. Make it clear, both by instruction and attitude, that you subscribe to the philosophy that, strictly speaking, there is no such thing as an accident. Accidents don't just happen—they are caused. The cause of an accident may not always be apparent, but it can usually be found. Common causes are lack of skill, poor work habits, poor attitudes, and—notice this—faulty instructions.

(5) The accident rate is not evenly distributed among workers. That is, persons who are frequently involved in accidents are "accident prone." Such people are dangerous to themselves as well as to those about them; they may, in fact, need to be referred to the safety officer or a psychiatrist. Therefore, if you discover that a trainee is having more than his share of accidents and if you have eliminated faulty instruction as a possible cause, report the facts to your supervisor for his action.

Exercises (639):

1. State how a person's potential traits are discovered.

2. Identify the next important step after the OJT program is planned, organized, and scheduled.

3. Indicate two very desirable results good instruction provides.

4. Cite the training principle you are using when you compare what you are teaching with something the student already knows.

5. Tell how to increase the effectiveness of the lecture method.

6. Clarify why discussion is a valuable training method.

7. Give the most effective training method to use when the training objective is the development of manual skills.

8. Identify the most effective training method.

9. *Situation:* During a training session, the trainer has to interrupt his instruction several times to get needed tools. Indicate the training technique he has failed to comply with.

10. *Situation:* After a trainer has watched a trainee successfully complete a training task for the first time, he puts the trainee *on his own* to do the job again, telling him to have it done when he (the trainer) returned from eating. Specify the training technique which the trainer is violating. Explain briefly.

640. Cite selected advantages of making job breakdowns and what each section of job breakdown involves and tell how to make such a breakdown on a job in which your experience is scant.

The nature of job breakdowns is the topic of this section.

Job Breakdowns. To present a complex operation to a trainee effectively, you should prepare an outline of the important steps and key points. One way to do this is to make what is termed a "job breakdown" for each job that you must teach. The job breakdown divides a complete job into several easy, progressive, and teachable units. Jobs such as these are taken from the Specialty Training Standard or Job Proficiency Guide.

Many OJT trainers may think they know a job when they really do not. Others may know the job so well that they neglect to clarify points that have become simple to them but which are quite confusing to the trainee. Still other trainers may know a job so well that they think that a teaching plan is not necessary at all. Unfortunately, all of these weaknesses are widespread. The problem is that, for some jobs, the breakdown may be as simple as telling the trainee to do this first, this next, and then do that. But many jobs, however, are complex and involve many operations. The complete performance of such complex jobs can overwhelm inexperienced airmen. So by breaking a job down into small teachable units, you can help the trainee learn it one step at a time. Of course, the degree to which a job must be broken down depends upon the trainee's past experience and learning capability as well as the complexity of the task. In each case, you must determine when a job has been broken down far enough to be easily taught and understood.

As a management device, the job breakdown usually consists of two columns. The first, titled "Important Steps," includes the simple, commonsense, step-by-step points that must be done. The second column, titled "Key Points," includes warning of hazards that can cause injury to the trainee or damage to tools and equipment, reminders of actions that make or break the job, and remarks about points that make the work easier.

Several ways exist to prepare a job breakdown. It is you who should determine, from your own experience and the type of job to be performed, which procedures are best. But by your using each of the following items, you can help you determine which procedure is appropriate.

- Some jobs may be so understandable that they can be analyzed and divided into simple, logical steps by merely thinking through the stages of the operation. Others may be too complex to break down without going through the entire operation and making notes on the performance of each part.
- You may need to break down a job in which you have had little experience. In such situations, watch the motions and steps used by someone more expert in the job than you.
- In every case, your objective is to find how you can best help the trainee to perform each operation safely, easily, correctly, and quickly. This involves the knacks, "the tricks of the trade," special timing, key points, and special information about what to look for, where to look, how to feel, and what to listen for in each operation.
- Job breakdown sheets are not necessarily intended for the trainee. Rather they are for your own use in clarifying and organizing your thinking about the job. Hence all job breakdowns need not comply with a particular format.
- All jobs are identified in a general way in the STS; many jobs are identified in the JPGs. However, you—the trainer—should prepare the job breakdown personally.

As you progress in your career, you will encounter many problem areas that have not been discussed here. You may also develop new training methods and techniques. In any event, you should use the material presented in this section to establish personnel guidelines—guidelines which will enable you to become more proficient in performing your role in the Air Force training program.

Exercises (640):

1. Give the advantage of breaking a complex job into small parts when you are teaching the job to another person.

2. State what each of the two sections of a job breakdown should include.

3. Tell how you should go about making a job breakdown on a job with which you have had little experience.

547

641. Concerning the AF Forms 623, 623a, 797, and the STS/JPG, tell how they are used, their significance, their contents, who determines if ECI forms on CDC VREs are kept in AF Form 623, the prescribing publication, the purpose of AF Form 623a, and the difference between an STS and a JPG, and use a typical situation to show how to record training.

This last segment of chapter 3 covers AF Forms 623, 623a, 797, and the STS/JPG.

AF Form 623. Remember that old saying, "If a thing is worth doing, it is worth doing well?" Well, let's carry that just a little further and say, "If a thing has been done well, it is worth recording." Much of the success of an OJT program is determined by how well the training records are maintained. Completeness and accuracy of entries on AF Form 623, On-The-Job Training Record, are often determining factors in deciding award or withdrawal of AFSCs. In addition, the entry into or withdrawal from OJT status and selectivity for preferred assignments must be recorded. The AF Form 623 is an official Air Force document. Therefore, it requires as much care on its upkeep as does any other official record. In any event, the knowledge and skill you apply to the proper care of training records are as important as the actual training you conduct.

The AF Form 623 is divided into several sections, which are used to record the airman's progress and proficiency in OJT. Each part is identified according to its designated purpose. This permits the recording of all training conducted on the job, in career development, and in formal courses. The form may also be used to record training that occurs *after* upgrading has taken place.

However, the AF Form 623 is not complete until a Job Proficiency Guide—which is an annotated Specialty Training Standard for the appropriate AFS—has been made a part of it.

Every AF Form 623 must be available to the supervisor. Accordingly, it is maintained ordinarily in the working area. When an airman is transferred, his AF Form 623 must accompany his personnel records to the gaining organization. If the gaining organization discontinues the training, the authority for discontinuance (AF Form 2096, Classification/On-the-Job Training Action) must be recorded on the AF Form 623.

Several forms are authorized to be included in the AF Form 623 in addition to the STS/JPG. These forms include AF Forms 797, which constitute a continuation form for the JPG; AF Forms 623a, which includes continuation forms for the various sections of the AF Form 623; AF Form 1096 and ECI forms generated during UGT (which, however, should be removed when the individual is upgraded); and Air Force automated training products produced under the maintenance management information and control system (MMICS). This is *not* a conclusive list of forms that can be included in the AF Forms 623, however, it is representative of the forms commonly required for the machinist specialty. AFM 50-23, *On-The-Job Training*, contains a complete list of authorized forms. NOTE: Certificates of completion of training are *not* authorized and should *not* be inserted in AF Forms 623. They should, however, be presented for viewing by the supervisor as proof of training when the supervisor documents the training in the AF Form 623.

AF Form 623a. As we have already stated, the AF Form 623a is used as a continuation sheet for various sections of the AF Form 623. The AF Form 623a, On-the-Job Training Record—Continuation Sheet, is inserted in the AF Form 623 to continue a section of the AF Form 623 which has been completely filled in. For example, section IV of the AF Form 623 exists for listing CDCs, ECI, USAFI, and other correspondence courses that have been satisfactorily completed. If this section becomes full, this type of information should then be continued on a AF Form 623a and maintained in the AF Form 623.

STS/JPG and AF Form 797. Specialty Training Standards are based on the Air Force specialty descriptions contained in AFM 39-1. An STS is a printed, detailed breakdown of a particular career field into individual tasks and knowledges. The fact that all significant job elements are reflected does not mean that supervisors are bound to gear proficiency training programs to adequately cover all STS elements. However, supervisors should gear job proficiency training programs to adequately cover all required elements of the STS. These elements comprise the duties and tasks of the positions to which airmen are assigned. The code key is reasonably objective. It provides a suitable means for achieving Air Force-wide standardization. The STS is used to train airmen to meet the minimum skill and knowledge requirements of the various specialties and skill levels.

What happens, though, when an STS is annotated by identifying tasks that the trainee will be required to perform by his position and duty assignment? Answer: At this point, the STS becomes a Job Proficiency Guide (JPG). The JPG provides the airman with a specific reference in an authoritative publication for each task he performs in his current duty assignment.

An STS may contain as many as 150 separate tasks, but if the airman is required to perform only 20 of these tasks, plus five locally assigned tasks, his JPG should be filled in only to the extent of the 25 applicable items. You can do this by circling the code key on the STS to indicate the level of skill for which he is training. These will be the tasks that the airman is actually performing in his duty assignment. The "locally assigned tasks" are the duties that the airman performs but which are not already identified on the STS. There must be added to the annotated items on AF Form 797, Job Proficiency Guide Continuation Sheet. The annotated items on the STS plus the additional items attached to it constitute a JPG.

This concludes our chapter about supervision and training; however, our next, final chapter, Maintenance Management, is closely related to this and will help you understand the scope of the maintenance organization of which the Air Force machine shop is an important part.

Exercises (641):

1. Tell why accurate recording of training is so important.

2. Indicate the form which must be included in an AF Form 623 before it is complete.

3. State who maintains the AF Form 623 on an individual.

4. Identify what determines whether ECI forms concerning CDC volume review exercises may be kept in the AF Form 623.

5. Cite the publication which outlines the procedures for filling out the AF Form 623 and accompanying forms.

6. Give the purpose of AF Form 623a.

7. Differentiate between an STS and a JPG.

8. *Situation:* You find that you must train your subordinates in a task that is not included on the STS. Tell how you should record this training.

Maintenance Management

YOU WILL FIND that the Air Force, like any other business organization, consists essentially of equipment, facilities, and people. The efficient use of this manpower and equipment is the responsibility of management personnel. AFM 66-1, *Maintenance Management*, establishes the maintenance management system applicable to all Air Force activities engaged in the maintenance of aircraft, missiles, aerospace ground equipment (AGE), avionics, training equipment, and communications equipment. Supervisors must completely understand and apply these policies and procedures to insure maximum utilization of all available resources. You and all assigned personnel, military or civilian, must also be trained in the maintenance management system to facilitate the timely accomplishment of the Air Force mission.

In this chapter, we will discuss the maintenance management system, beginning with the function and responsibilities of the Deputy Commander for Maintenance and the staff units. We will also discuss the maintenance system including maintenance data collection forms, reports, and materials processing. Finally, we will look at the various aspects of the maintenance inspection systems.

4-1. Deputy Commander for Maintenance and Staff

One key to understanding why your shop is required to perform the many tasks levied against it is for you to be knowledgeable about the responsibilities and functions of those over you who control and manage the maintenance organization. In this section, we will try to familiarize you with the tremendous responsibilities and functions of the Deputy Commander for Maintenance and his staff units.

642. State the main functions and responsibilities of the Deputy Commander for Maintenance (DCM), especially concerning safety and training, and specify the relationship of the machinist to those responsibilities.

The duties and responsibilities of the DCM, especially as related to the machinist, are our subject here.

Deputy Commander for Maintenance. The Deputy Commander for Maintenance, termed the "DCM," manages all of the maintenance complex. Thus, the DCM must plan, schedule, control, and direct the use of all maintenance resources to meet mission requirements. With the aid of the staff agencies, he must provide the essential guidance and direction for subordinate activities to implement and comply with assigned maintenance policies and technical instructions.

In addition, the DCM is responsible for insuring that the maintenance performed on the assigned equipment is of high quality and that it is performed in a timely manner. This responsibility makes the success of the DCM's job dependent upon the actions of each and every specialist within the maintenance complex. Quality maintenance depends upon the integrity and concern of each individual specialist or technician, who must accomplish his assigned task regardless of the environmental conditions. You can see, then, that if you do poor quality work, it can adversely affect competence of the whole maintenance complex, including the DCM.

The DCM must also insure that effective safety programs are established and adhered to throughout the maintenance complex. He is responsible for establishing an efficient training program and for reviewing monthly training plans and schedules. He must also manage the financial operation of the maintenance organization and establish effective resource conservation programs within the maintenance complex.

Of course, the foregoing are not nearly all of the responsibilities assigned to the DCM by AFM 66-1, Volume 2. Still, even these few should be enough to point out to you the complexity of his position. As we have already stated, to effectively discharge his duties and responsibilities, the DCM must have the *complete support* of each individual assigned to him.

Exercises (642):

1. Specify the main function of the DCM.

2. Tell how the kind of work you do as a machinist effects the success or failure of the DCM.

3. Give the DCM's responsibilities concerning safety and training.

643. Concerning the basic functions of units making up the DCM's staff, give the main ones related to maintenance, the maintenance control unit's divisions, and the function and responsibilities of this and other units related to maintenance.

As a machinist-supervisor, you must understand the DCM's staff functions—our topic at this time.

DCM Staff Functions. From our discussion of the responsibilities of the DCM, you have probably already concluded that even the few we have mentioned take up much more research and work than any one person can do. For this reason, the DCM is provided with a group of staff units under his direct supervision. Of these, two, maintenance control and quality control, are responsible for the management of the quantity and quality of maintenance production. Other units, which are assigned tasks not directly associated with direct production efforts, are grouped together as management support functions and programs and mobility.

Maintenance control. Maintenance control is the staff agency that is responsible for directing the maintenance production activities, authorizing the expenditure of resources and controlling the actions required to support the mission. Maintenance control manages the planning, scheduling, directing, and controlling of all maintenance performed on assigned and transient vehicles and related equipment. To accomplish this task, maintenance control is divided into these three sections: (1) job control, (2) plans and scheduling and documentation, and (3) materiel control, which are covered in that order next.

a. The job control section. This is the section charged with the task of directing and controlling the use of maintenance resources. It must also implement the maintenance plans and schedule the accomplishment of unscheduled maintenance requirements. Job control is the section authorizing and assigning the flightline dispatch jobs and priorities to which you must respond. Also, the job control people monitor the specialist availability throughout the maintenance complex and direct their utilization in accomplishing the required maintenance tasks as they occur. This is why it is so important for each shop to notify job control when there is a change in the specialist availability in the shop or when a specialist completes an assigned task. To do their job properly, job control must know how many specialists are available for dispatch at all times.

Job control also establishes measures to manage the powered AGE equipment. They coordinate closely with the AGE dispatch unit and the shops who require the use of AGE equipment. Thus, they must know what units are available and their location. In addition, they assign job control numbers which we will discuss in more detail later in this chapter.

b. The plans and scheduling and documentation section. In this section are compiled the maintenance data for the DCM. This section also must brief the DCM on projected changes needed to meet mission requirements. Furthermore, it is the people who work in this section who compile and publish monthly and weekly maintenance plans, and they must establish schedules for compliance with TCTOs before their specified time limits.

c. The materiel control section. This section provides coordination between maintenance, on the one hand, and supply, on the other, for needed parts and equipment as such is required. It is composed of (1) the supply liaison function and (2) the production control function. Of these, the production control function is responsible for scheduling in-shop production jobs.

Quality control. This unit is responsible for insuring quality and safe maintenance. Its personnel inspect and evaluate maintenance and facilities and coordinate closely with supervisors in an effort to improve the maintenance methods. They also maintain the master technical order file for the maintenance complex. In addition, quality control administers the Maintenance Standardization and Evaluation Program (MSEP) and manages the materiel deficiency and technical order improvement reporting programs.

Management support functions. These functions, as we have stated already, perform duties not specifically related to the direct control of maintenance production. These functions are: (1) administration, (2) production analysis, (3) training management, and (4) programs and mobility, discussed next in that order.

a. The administration function. This function accomplishes all of the administrative activities for the DCM. Its personnel supervise the keypunch activity when it is assigned to the maintenance complex, and they sort out and group all AFTO Forms 349 before submitting them to the keypunch activity. They are also responsible for insuring the proper distribution of all maintenance correspondence, reports, and publications.

b. The production analysis function. It is this function which is the primary management information source for the DCM. Its personnel scan the various maintenance data reports and listings in an effort to identify weaknesses found in workcenters, in equipment end items, in maintenance practices, or in management actions. Part of production analysis's many responsibilities is to assist supervisors in proper application and interpretation of man-hour and maintenance data publications and reports. This unit also assigns work center codes.

In addition to the foregoing, this section is the control point within maintenance for the base level inquiry system (BLIS). Consequently, when a supervisor needs to know how his specialists have been used during a certain period of time — including the type of job, the time required to complete each job, and the number of times that a particular job has been done — he can request production analysis to extract that information for him from BLIS, in which all maintenance data is stored on computer tapes. Because the type of information analysis that can be obtained in this way through BLIS is extensive, it should be used by all maintenance managers to enhance their operation.

c. The training management function. This is the function which assists unit training sections in the management of maintenance training and management training requirements. Its personnel are those who schedule and monitor the maintenance management training program and consolidate unit requests for maintenance training in order to identify the total requirements for the maintenance complex. In some instances, training management may be the centralized agency for controlling and managing the UGT program. In these cases, this section performs all of the responsibilities of each unit training section.

This latter function (training management) also manages and administers the MMICS training subsystem. Under this system, all training data, including training schedules, requests, completions, due dates and historical data is stored in computers and published in various reports and listings to insure that required training is obtained in a timely and efficient manner.

Programs and mobility. This is the last function taken up in our discussion of the DCM staff. It manages the manpower, facilities, and financial resources for the DCM. It is directly concerned with the number of personnel assigned to the maintenance complex and with the positions to which they are assigned. Its personnel initiate requests for changes to the unit manpower authorizations. They also prepare the budget requirements for the maintenance complex and determine the facilities requirements for the organization.

In conclusion, the scope of the functions of the DCM staff is truly extensive. Yet, all of these functions are available to each supervisor and/or manager within maintenance and, properly used, can help him/her establish the most efficient and productive maintenance operations.

Exercises (643):

1. Name the two main staff units under the DCM that are concerned with maintenance production.

2. List the divisions of the maintenance control unit.

3. Match each function given in column B with its corresponding maintenance control division, found in column A, by writing the correct number-coded function (column B) beside its associated letter-coded division (column A). NOTE: Each item in column B may be matched once or more than once.

Column A	*Column B*
___a. Job control.	1. Publishes weekly and monthly maintenance plans.
___b. Plans, scheduling, and documentation.	2. Schedules the accomplishment of unscheduled maintenance.
___c. Materiel control.	3. Has production control as one of its functions.
	4. Schedules in-shop production jobs.
	5. Controls flightline dispatch specialists.

4. Name the staff unit that manages the technical order improvement program.

5. List the functional units contained in the management support group.

6. Clarify briefly the responsibilities of the production analysis function, indicating how its personnel can help the maintenance supervisor.

7. Cite the DCM staff function responsible for making requests to change the unit manning authorizations.

4-2. Maintenance Systems

In this section we will examine the types of maintenance performed by Air Force machinists and the maintenance data collection system. We will discuss the use of certain maintenance data collection forms and we will also look at the procedures for controlling materials as they flow through the shops.

644. State the types of maintenance performed by the machinist and the organizational maintenance system's (OMS) responsibility for insuring maintenance is accomplished and, given a hypothetical situation involving maintenance, the level of maintenance being performed.

What are the types of maintenance which a machinist performs? These are discussed next.

Maintenance Systems. What is termed "maintenance" refers to the normal upkeep and preservation of aircraft and associated operating equipment which must be kept in reliable condition. To achieve such maintenance, it is necessary to use a system that will insure the timely accomplishment of important tasks. A system that meets this requirement is one of *regularly scheduled maintenance and repair actions*. Various levels of maintenance are charged with the responsibility of performing specific maintenance tasks. The organizational maintenance system (OMS) facility performs minor maintenance on the assigned aircraft. This is referred to as *organizational level maintenance* and can include such things as removal and replacement of parts, servicing, and various types of inspections. Field maintenance activities perform intermediate level maintenance functions. This is considered major maintenance and is *middle level maintenance*. Maintenance beyond the capability of the intermediate maintenance facilities on a base is accomplished at a depot. Thus, *depot level maintenance* is the highest level of maintenance and is performed at bases that are specifically designated to perform this function. At a depot base, they have the capability of rebuilding parts, overhauling equipment, and in some case, completely overhauling an aircraft.

You will be working primarily in the intermediate maintenance level. At this level, maintenance may be classified as (1) scheduled or (2) unscheduled. *Scheduled maintenance* is a job that can be planned in advance. Examples include TCTOs and periodic inspections. In contrast, *unscheduled maintenance* is that which is not planned. Examples of this type would be malfunctions discovered by aircraft crew chiefs and other maintenance personnel, such as a cracked wing spar or a broken generator stud on an aircraft engine.

In the Air Force, the organization to which an aircraft is assigned has the responsibility for its upkeep. In most cases, this is OMS, and it is responsible for getting the required work done, even though its personnel do not perform all of it themselves. When the work is beyond their level of maintenance, they must request assistance from the specialists in the intermediate level facilities, which, as we said, includes the machinist.

Exercises (644):

1. Specify the maintenance level in which you perform as a machinist in field maintenance.

2. *Situation:* Suppose you were assigned as a machinist to a facility specifically designated to completely overhaul certain types of aircraft. Name the level of maintenance in which you would most likely be working.

3. Indicate why OMS is responsible for insuring that the maintenance you perform on the assigned aircraft gets completed.

645. Give the purpose and clarify the operation of the maintenance data collection system and the man-hour reporting system.

That you know and understand what the maintenance data collection system and the man-hour reporting system are is assumed; so these are this segment of this volume's topics.

Maintenance Data Collection System. The maintenance data collection (MDC) system provides for the reporting of maintenance actions as they are accomplished. The recorded information is then keypunched and processed in report form for management information requirements.

There are many and varied uses made of MDC information, starting at work centers and running through the complete spectrum of maintenance and materiel management. This information is also provided to industry for consideration in new equipment design. Specific uses of the output products from computer programs are included in USAF directives. These uses are also included in command regulations and manuals that prescribe management requirements.

Base level use of maintenance data is prescribed in AFM 66-267, *Maintenance Data Collection System*. At base level, the MDC system provides the means of managing assigned equipment resources and planning and scheduling maintenance. It also provides the means for validating and initiating corrective action on maintenance problems. The MDC system is a key source of information for assessing maintenance requirements. More specifically, at base level, the MDC system provides:

- Production credit information regarding the type of work accomplished, the work center(s) that did the work, and the equipment on which the work has been accomplished.
- Equipment maintenance schedules and inventory information for maintenance requirements established on a calendar basis.
- Direct labor hour expenditures by work center and type of equipment, in either detailed or summary form. This includes labor expended for tenant activities on special projects.
- Material failures and equipment discrepancies, in composite form by type and model of equipment.
- Configuration status accounting for both outstanding and accomplished modifications.

Data in the MDC system is made available to base level maintenance activities through daily or monthly reports. Daily error listings are also produced at base level to aid in maintaining accurate information.

The MDC system serves as the primary source of information for configuration status accounting and is used at all levels of management for the following purposes: (1) to identify equipment configuration; (2) to assure accomplishment of time compliance technical orders (TCTOs), (3) to project workload and scheduling requirements, and (4) to provide mechanized historical records for designated equipment. In addition, this program provides information to AFLC for validating individual modification requirements. It is also used as an aid in determining kit distribution requirements and TCTO recision dates. Configuration management requirements and procedures are outlined in AFR 65-3, *Configuration Management*, and TO 00-20-4, *Configuration Management System*. The data for weapon systems and equipment managed under the Advanced Configuration Management Systems (ACMS) is used for the purposes just discussed. It is also used for maintaining accurate configuration status, by serial number, for selected high cost as well as mission significant items. This data enables AFLC to provide support with a minimum number of spares and to distribute these spares on a timely basis. This is done by providing precise removal and replacement predictions. The ACMS is also used to maintain information on the mission capability of weapon system or equipment by serial number. This information is used as an aid in equipment maintainability and reliability.

The key to the success of the MDC system is accuracy—from the specialist filling out maintenance forms all of the way through the highest level report. When the specialist or supervisor *pads* maintenance forms, whether for the sake of expediency or for manpower justification attempts, the erroneous information makes accurate material and maintenance trend analysis extremely difficult.

Man-hour reporting. The man-hour reporting system, often termed "exception time accounting" (ETA), is not used in its original form in units that have implemented MMICS. Under the original ETA system, each hour of duty time was accounted for on each assigned individual based on a specified work week. If an individual on duty took 2 hours off to get a haircut, a computer type card (AF Form 1457, Daily Exception Card) was filled out noting the 2 hours of nonproductive time. This was necessary to update the Master Roster, which not only listed each person assigned to the shop but also listed the number of productive work hours that were available for each individual for the month. The supervisor was to insure that a specified portion of that available time was actually spent on the job.

An important part of good supervision and management is keeping track of the number of hours of actual productive work (productive-direct) that each work center is producing. For example, each individual in a work center spends several hours a month meeting various appointments, attending commanders call or training classes, etc. These are all considered *productive-indirect*. A supervisor must control and document the number of productive-indirect hours expended by his subordinates if he is to effectively meet the mission requirements of his shop. He must insure that as many normal duty hours as possible are expended on *productive-direct* labor and that those hours of productive-indirect labor have been documented.

In units where MMICS has been implemented, the supervisor uses two mechanized reports to keep track of his work center's man-hour utilization; the Maintenance Personnel Listing, which replaces the old Master Roster, and the Monthly Man-hour Summary. With these two reports, the supervisor can see the numer of productive-direct man-hours his work center could produce for the month, if each assigned person actually has worked every single duty hour. The Monthly Maintenance Summary shows the supervisor at the end of each month just how many of those available man-hours were actually spent on productive-direct labor. The number of productive-direct hours on the report comes from the MDC forms (349s, etc.) turned in by the work center during the month. The number of productive-direct man-hours available for the month are based on the number of people in the work center who are assigned to a productive labor position (designated by a *Labor Code:* code 100) and multiplied by the number of duty hours in the month. Still, the supervisor must strive to keep the nonproductive man-hours (undocumented time off such as for haircuts, etc.) to a minimum. His failure to do this will result in workload backlogs or a loss of manpower authorizations or both. Why? Because the number of people assigned to a particular work center is based to a large extent on the number of productive man-hours, both direct and indirect, expended by that work center in a given month. If it is continuously low in relation to the hours available, it will appear that there are more people assigned than needed.

Productive-indirect hours are also documented on AF Form 349, using special codes which are listed in TO 00-20-2 and aircraft and equipment code manuals (-06 technical orders). The codes cover such things as alert duty, compensatory time for overtime, details and squadron or base duties, leave, and maintenance training.

Exercises (645):

1. Relate the overall purpose of the MDC system.

2. Tell how the data that is collected by the MDC system is made available to base level maintenance activities.

3. State the purpose of configuration status accounting in the MDC system.

4. Where MMICS has been implemented, indicate which two reports the supervisor uses to keep track of the man-hours expended in his work center.

5. Specify how the number of productive-direct/indirect man-hours that are expended by a work center is obtained for inclusion on the monthly man-hour summary.

6. Tell why the supervisor should strive to minimize the number of nonproductive or undocumented man-hours expended by his work center.

7. Indicate how productive-indirect labor hours are designated on MDC forms.

646. Give the characteristics, purposes, and uses of the basic MDC forms and codes and the meaning of selected job control numbers and identify the directives prescribing the procedures for their use.

This part of the text discusses the MDC forms, AFTO Forms 349 and 350.

MDC Forms. The basic maintenance data collection forms used by machine shop personnel are the AFTO Form 349, Maintenance Data Collection Record, and the AFTO Form 350, Reparable Item Processing Tag. The AFTO Form 349 is used for documenting personnel actions on equipment end items and on assemblies, subassemblies, or components. In addition, it is used to record productive-indirect labor, as we have stated earlier. The AFTO Form 350 is used as a data source for documenting off-equipment AFTO Forms 349. It is also used as a routing tag for parts and assemblies as they flow through the maintenance shops. Now let's examine the procedures for using each of these forms.

AFTO Form 349. There are many ways to document actions on the AFTO Form 349, depending upon the type of action involved. For example, certain blocks and columns on the form are filled out when you document on-equipment work. But when off-equipment work is accomplished, the required blocks and columns are different. And even within these two classes of work, there are several ways of documenting the forms, depending upon the type of equipment or action involved. Therefore, it would be futile for us to try to print all of the various requirements for documenting these forms. Rather, you should become familiar with the 00-20-2 series technical orders. TO 00-20-2 lists the required blocks and columns to document for various types of equipment and personnel actions.

Several codes are used to document AFTO Forms 349, such as the (1) job control number, (2) equipment classification code, (3) identification number, (4) type maintenance code, (5) component position number, (6) work center code, (7) labor category code, and the (8) command/activity identification number. In addition, there is the (9) action-taken code, the (10) when discovered code, and the (11) how malfunctioned code. We will briefly discuss how each of these codes is obtained and used.

a. The job control number (JCN). This is a seven-character number that is used to control and identify maintenance actions. The first three characters identify the Julian date; for example, 052 means the 52nd day of the year. The last four characters identify jobs and normally consist of a daily or monthly job sequence number such as 0001 for the first job of the day. In our example, then, 0520001 means the first job on the 52nd day of the year. When the job is in conjunction with a phase inspection, the fourth character is alphabetic to designate the particular phase involved. TO 00-20-2 contains a complete explanation of the use and construction of the JCN, which is assigned by the maintenance control complex.

b. The equipment classification code. This code is placed in the block on the AFTO Form 349 marked EQ/CL. It consists of three characters, which identify a specific kind of equipment or type of work in support of that equipment. Take, for example, the code for B-52G aircraft, which is A BG; for HH-43 helicopters, A HG; and for shop manufacture in support of aerospace equipment, S SA, etc. You can find a complete list of official EQ/CL codes in TO 00-20-2.

c. The identification number. This constitutes a six-character code, in accordance with AFM 66-267, that identifies specific equipment on which work was performed. Of the six characters, the first identifies the owning work center. The second is the first character (prefix) of the EQ/CL. Finally, the last four digits normally make up the last four digits of the equipment serial number.

d. The type maintenance code. This code is a one-character code that identifies the type of work that was performed, such as scheduled or unscheduled maintenance. These codes are contained in the applicable code manual (-06) and in AFM 300-4.

e. The component position number. This number is a one-digit number used to identify the position of an engine on an aircraft. An entry is required in the COMP POS column when work is accomplished on an engine or component system. TO 00-20-2 explains this number's use.

f. Work center codes. These codes are five-digit codes that identify work centers that accomplish the work. The standard work center codes are listed in attachment 2 to TO 00-20-2 and are assigned in accordance with AFM 66-1.

g. The labor category code. This code is a single-digit number used to identify the types of man-hours expended; military or civilian, overtime or regular duty hours, etc. Attachment 5 to TO 00-20-2 lists the codes for each category.

h. The command/activity identification number. This number is used to identify transient aircraft that have no asigned ID number. It is entered in the column entitled CMD ACT ID. AFM 300-4 must be consulted for these numbers.

i. Action taken codes. These codes consist of one character, which identifies the action that has been accomplished, such as the removal and replacement of a component.

j. When discovered codes. These codes consist of one character and identify when a defect or maintenance requirement has been discovered.

k. How malfunctioned codes. These codes consist of three characters and identify the nature of the defect, such as cracked, broken, or stripped.

Complete lists of the last three codes just mentioned can be found in AFM 300-4 and the -06 code manuals also list all codes applicable to that particular equipment.

AFTO Form 350. The AFTO Form 350 is a two-part perforated card that serves as an identification and status tag. The lower part contains most of the same information given on the top part. The lower part is normally retained in the production control activity as the components go to the various maintenance shops and is updated as the status of the part is changed. The top part is attached to the component and stays with it as it flows through the shops. It serves as a source document for information required in completing AFTO Form 349 repair actions on the components. Procedures for the use of this form are outlined in the 00-20-2 series TOs.

Exercises (646):

1. Name the two basic MDC forms used by machine shop personnel.

2. State the two main purposes of the AFTO Form 349.

3. Identify the publications prescribing the procedures for filling out AFTO Forms 349.

4. Clarify the meaning of job control number 1950002.

5. Indicate the code entered in the AFTO Form 349 block labeled EQ/CL.

6. State the purpose of the code called for in item 5.

7. Tell the publication containing a complete list of equipment classification codes.

8. Clarify how the identification code is dependent upon the equipment classification code.

9. State the characteristics and purpose of the component position number.

10. Indicate the code used on AFTO Form 349 which identifies whether a specialist is military or civilian and whether or not that person has worked overtime.

11. Identify the publications giving complete or partial lists of When Discovered codes, How-Malfunctioned codes, and Action Taken codes.

12. Give the purpose of the two parts of the AFTO Form 350.

647. Give the meaning and use of the various codes employed in the processing and controlling of material through maintenance shops, identify the controlling agency, and given hypothetical situations, provide the code involved and its use and your likely course of action.

The processing and controlling of materials is vital to machinist-supervisors; so these subjects will be examined in this unit.

Processing and Controlling Materials. In the Air Force, many commonly used names and phrases are shortened into abbreviations or codes for the purpose of speeding up communications. This is especially true when it comes to processing materials through maintenance shops. You have probably already heard people use codes like DIFM, AWP, NRTS, or AWM. Well, each of those codes have a specific meaning that you should understand.

To begin with, the unit that controls and processes reparable items through the maintenance shops is the

Reparable Processing Center (RPC). Its personnel are normally assigned as part of the materiel control function under the Deputy Commander for Maintenance (DCM). Now, let's follow an item through a processing cycle and see how those codes are used.

Suppose that the engine shop found a malfunction in a coupling on the power-takeoff shaft of an aircraft engine. The part must be removed to be fixed; so the engine shop orders a new part from supply. They give the engine shop a document number and issue the new part. The engine shop then removes the damaged part and attaches an AFTO Form 350 tag containing the document number. Supply uses the document number to be sure that it receives a like part for the one it issued. Therefore, this item must be controlled; it is referred to as DIFM-*due in from maintenance*. In other words, to supply this code means that they are short one of these parts on their parts shelf but the part will be returned as soon as it has been processed through the maintenance shops. Not all parts are considered to be DIFM. Generally speaking, DIFM items are either high value items or limited availability items, and they are normally component parts of end-items.

Now, back to our coupling. The engine shop takes the part to RPC (sometimes termed the "Reparable Assets Control Center, (RACC)." It insures that the AFTO Form 350 tag is properly filled out and retains the lower portion of the tag for its records. Its personnel also assign a repair priority and determine the shop responsible for the repair action. Suppose, for the sake of the example, that RACC sends it to the machine shop to disassemble, *mic* and check the various parts, and replace those parts that cannot be repaired. But, then, when the part arrives in the machine shop, the supervisor determines that he will not be able to begin work on the part until the next day because of other priority work. This waiting time is noted by RPC and is referred to as AWM—*awaiting maintenance*. The next day, when the supervisor assigns someone to work on the part, he immediately notifies RPC, which changes the status of the coupling from AWM to in-work.

Now, suppose that when the machinist disassembles the coupling, he finds that he could repair it if he had a new bearing for it. When he contacts Supply, he is told that the bearing is not on hand, but it will be back-ordered. This would stop the maintenance action, and RPC must again be notified. At this point, the coupling is said to be AWP—*awaiting parts*, and it must be put aside until the bearing is delivered by Supply. But, what would have happened if the machinist had found that nearly every part in the coupling would have to be replaced?

Normally, if the cost of repair (replacing all the individual parts) would be 75 percent or more of the replacement cost for the complete unit, the part is considered to be NRTS—*not repairable this station*. There are many reasons why the NRTS code is used; i.e., repair cost too high, parts not obtainable, repair facilities not adequate, repair tools not available, etc. Each of these reasons is identified by an *action taken* code which we have discussed in our objective on AFTO Form 350 documentation. The use of these NRTS codes is strictly controlled, however, and you should always check with the shop supervisor or RPC before using them. In the case of our coupling, the cost of repair would have been too high and the NRTS code for *condemned* would have been used. The disassembled part would have been returned to RPC, which would clear its records and send the part back to Supply. Supply would then go to the manufacturer or depot for a replacement part to replenish its inventory.

However, in our original example, in which the machinist was waiting for a new bearing, when Supply eventually issued the bearing, the machinist would then check it and reassemble the coupling *in accordance with the applicable TO*. As soon as Supply issued the bearing, RPC would again change the status of the coupling, from AWP back to in-work.

Once the machine shop has completed their action on the coupling, the data from the AFTO Form 350 tag is transferred to an AFTO Form 349 for input into the MDC system as we have described in a previous objective. The part is then properly packaged and the appropriate condition tag (serviceable, serviceable with parts missing, or condemned, as we discussed in Volume 1 of this CDC) is attached. The part is then sent to Supply through RPC, and the records are cleared. More specific information on the control of material through the maintenance shops can be found in TO 00-20-3.

Exercises (647):

1. Give the controlling centers for processing material through the maintenance shops.

2. Tell the meaning and the use of the abbreviation "DIFM."

3. *Situation:* A DIFM part has been delivered to your shop for repairs, but your workload will not permit you to begin work on it for 2 days. Indicate the code used to show the status of the part during those 2 days and what it stands for.

4. Tell what AWP stands for and when it is used.

5. *Situation:* A damaged engine gear box is in your shop for repair. After finding the trouble, you determine that the base does not have the equipment to make the needed repairs in accordance with technical data. Indicate what your probable course of action will be.

4-3. Inspection Systems

The Air Force has learned from experience that the best time to perform maintenance on a piece of equipment is before it breaks down. This is especially important when that equipment is aircraft. When something malfunctions or breaks during a flight, the results can easily be disastrous. But how do you find potential problems before they become actual malfunctions? That is where the inspection system comes into the picture. In this section, we will discuss the purpose and structure of the maintenance inspection system, including the various inspection reports and how they can be used to improve the maintenance efforts.

648. State the purpose of inspections done by maintenance personnel and how the Air Force insures inspection standardization, list the phases of an inspection, and given a hypothetical situation, identify the inspection phase involved.

What you need to know about maintenance inspections, including their main phases, is covered in this part of this chapter.

Maintenance Inspections. The primary purpose of the maintenance inspection system is to locate and repair defects in equipment and to repair those defects and their causes before they cause total failure of a part or subsystem. Take, for example, finding a crack in the wing spar of an aircraft before it causes wing failure in flight. The inspection system incorporates these four phases of inspection to insure the integrity of a piece of equipment: (1) the preinspection phase, (2) the look phase, (3) the fix phase, and (4) the postinspection phase.

The *preinspection phase*, the first phase, consists of a preinspection meeting, aircraft preparation, and inspection area preparation. The *look phase* follows the inspection phase and consists of conducting an inspection of the aircraft in accordance with technical manuals and workcards. The third, *fix phase* consists of correcting the discrepancies found during the look phase. Finally, the last or *postinspection phase* follows the fix phase and consists of an operational check of the item repaired or replaced.

Any maintenance that can be accomplished to avoid major problems later on is important. The Air Force uses several types of inspections, and each one is geared to prevent further malfunctioning. To insure that nothing is overlooked during an inspection, the Air Force has developed -6 technical orders (which list all items to be checked). By thumbing through the pages of a -6 technical order, you will find such words as *loose, binding, chafed, broken* and *secure*. These are the conditions that have in the past caused troubles and generally can be identified by looking and feeling. They can be repaired prior to a system failure which could result in serious damage.

Exercises (648):

1. Give the primary purpose of the various inspections performed by maintenance personnel.

2. List in order the four phases included in the inspection.

3. *Situation:* During an inspection, a maintenance inspector checks the work of a specialist who has just replaced a damaged stud on an engine gear box. Identify the phase of the inspection in which he is involved.

4. Tell what the Air Force has done to insure standardization in what each inspection requires.

649. State the authorized inspection concepts, identifying the types of inspections each includes, and given a hypothetical situation, indicate the concept in operation.

Machinists, too, must grasp the inspection concepts and inspections affecting their work. Thus this section acquaints you with these topics.

Inspection Concepts. Maintenance inspections are performed under three authorized inspection concepts. These are the periodic, phased, and isochronal concepts. *Isochronal* means at equal intervals. To satisfy the same total maintenance requirements under each concept, different groups of named inspections are used, depending upon the type of maintenance concept. The nine named inspection element requirements are listed in figure 4-1. Study this figure before going on to an explanation of what each inspection does and when it is performed.

The purpose of aircraft inspections is to determine whether or not the aircraft is airworthy. However, each named inspection has a specific function,

Periodic Concept	Phased Concept	Isochronal Concept
1. Preflight	Preflight	Preflight
2. Thru-flight	Thru-flight	Thru-flight
3. Basic postflight	Basic postflight	-
4. Hourly postflight	-	-
5. Periodic	-	-
6. -	Phased	-
7. -	-	Home station check
8. -	-	Minor check
9. -	-	Major check

Figure 4-1. Inspection concepts and their elements.

depending upon requirements. Thus, one of the scheduled maintenance inspections normally performed by organizational maintenance is the *preflight inspection.* The preflight inspection is performed before the first flight of each day. This inspection is a visual and operational check to determine whether or not the aircraft is prepared for flight. Another scheduled maintenance inspection is the *thru-flight inspection.* The thru-flight inspection is designed for use on cargo aircraft utilized for regularly scheduled airline-type operations. It consists of checking the aircraft for flight continuance by performing visual examinations to discover defects or maladjustments which, if not corrected, would impair safety of the next flight.

Another inspection is the *basic postflight inspection.* A check to determine whether or not the aircraft is suitable for another flight describes the basic postflight inspection. It is performed after each flight. There is also an inspection called the *hourly postflight.* It is accomplished upon the accumulation of a specified number of flying hours and is due at the completion of the mission during which the specified number of flying hours is completed. The hourly postflight augments the basic postflight by adding the inspection of certain components, areas, and systems not normally checked during the basic postflight.

The next inspection to be covered is the *periodic inspection.* Like the hourly postflight inspection, the periodic is performed upon accrual of a specified number of flying hours. The periodic inspection is a thorough and searching inspection of the entire aircraft. A complete periodic inspection includes requirements of the basic and hourly postflight inspections, along with the inspection of components which require less frequent inspection. Of course, all of the scheduled inspections covered so far are used in the *periodic concept.*

Under the *phased concept,* three of the five inspection elements of the periodic concept are repeated, as shown in figure 4-1. These are the preflight, thru-flight, and basic postflight. One other inspection element is included in the phased concept; it is called the *phased inspection.* The phased inspection is a consolidation of the periodic and the basic postflight or the hourly postflight, thus satisfying the same total inspection requirement. The phased inspection is designed to reduce the length of time an aircraft is out of commission for any given inspection. This is accomplished by consolidating inspection requirements into small packages. To provide the flexibility of maintenance scheduling required by the phased concept, the phased inspection will be performed at intervals specified by locally established controls.

The *isochronal concept* is the third and last of the three authorized inspection concepts used in the Air Force. See figure 4-1 for the inspections listed under the isochronal concept. The three inspection requirements not used in the periodic or phased concepts are the (1) home station check, (2) minor check, (3) major check. The *home station check* is performed at specified intervals and concurrently with the major and minor inspections. Of the two remaining inspections, the *minor check* and the *major check*, the first enlarges the home station check. In contrast, the major check is a thorough and searching inspection of the entire aircraft. Both the minor and major check, although different in purpose, are performed upon the accrual of a specified number of calendar days and are due at the end of the mission during which the specified number of days are accrued.

Schedules for inspections vary greatly. You may find some inspections scheduled to be just a few hours apart, while others may be up to many months apart. The intervals have been established from data collected and analyzed from previously submitted data forms.

As a machinist, you will not normally be involved directly in these inspections except for making repairs found during them. However, you need to understand them because the types of inspections determine certain codes used in the MDC system, such as in the job control number, which we have discussed earlier.

Exercises (649):

1. Name the authorized inspection concepts.

2. Differentiate between the basic postflight and the hourly postflight inspections.

3. List the inspections conducted under the concept of the periodic inspection.

4. *Situation:* Suppose that an aircraft maintenance organization operating on your base does *not* include among their inspections either the basic postflight inspection or the hourly postflight inspection. Indicate the concept under which they are most likely operating, which allows them to act in this way.

650. State the purpose of the USAF materiel deficiency reporting and investigating system and differentiate among the types of categories and methods of reporting.

One of the benefits obtained through the Maintenance Data System is the discovery of equipment deficiencies. Recurring defects and repeated maintenance actions on a specific piece of equipment are quickly identified. This identification makes it possible for engineering and technical agencies to make improvements through modification programs. Also, reports are developed and sent to other Air Force installations, so that similar deficiencies can be corrected on like equipment. TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigation System*, outlines the procedures to follow when a deficiency is discovered.

USAF Materiel Deficiency Reporting and Investigating System. The basic purpose of this system is to establish methods that will feed back deficiency data to activities responsible for development, procurement, and other logistics management functions, so that action can be initiated to correct and prevent material, design, and quality deficiencies. The procedures of this system apply to all USAF agencies, including depot level maintenance facilities, civil contractors, and Air Force test and evaluation teams or forces. This includes subsidiary or affiliated agencies for which USAF has support responsibilities, such as Air Force Reserve (AFRES) and Air National Guard (ANG).

The responsibility for clearance and control of materiel deficiency reports prescribed in TO 00-35D-54 is assigned to the quality control staff, in accordance with AFM 66-1. Activities that are not governed by AFM 66-1 will establish a clearance and control office patterned after the quality control organizations prescribed in AFM 66-1. The organization that is responsible for the clearance and control of materiel deficiency reports will assign report control numbers to all materiel deficiency reports. They will maintain AF Form 2423, Technical Order Improvement or Unsatisfactory Materiel Reports Log, for recording Category I and Category II reports. Report control numbers will be assigned in numerical sequence, regardless of the type of report submitted.

The person discovering the deficiency will prepare, process, and route materiel deficiency reports as prescribed in TO 00-35D-54. The Deputy Commander for Maintenance of the submitting activity will review all materiel deficiency reports prior to submittal to insure that they are reported under the correct method and are routed correctly. Emphasis will be placed on identification of materiel deficiencies which will be the subject of Category I reports to insure that only true safety conditions are reported as Category I (discussed just below).

Categories of Deficiencies. Different categories of deficiency reports have been developed in order to indicate the seriousness and the effect it has on the operational efficiency of a unit. Presently, two categories are in use: (1) Category I reports, and (2) Category II reports.

Category I report. The Category I report is a report of emergency conditions of a safety nature on all types of equipment. These conditions are defined as follows:

(1) Accident or incident—An unexpected or unsought event that does damage, or could cause

damage, to persons or property and which is not caused by enemy action.

(2) Nuclear safety deficiency—Any material, engineering, or procedural deficiency which could cause (or contribute to) a nuclear accident, incident, or deficiency.

(3) Critical safety deficiency—Malfunction of a part, component, or installation which results in an unacceptable hazard that requires corrective action be initiated as soon as possible for personnel and system survival.

(a) For *aircraft*, any materiel or installation deficiency that results in an inflight requirement to use prescribed emergency procedures or other extraordinary means to avert further damage or injury to personnel should be reported as Category I. This requirement specifically includes, but is not limited to, flameout or engine failure of any engine, or significant loss of thrust or power, during the takeoff, landing approach, or go-around phases of flight. Category I reports are not required when corrective action for an inflight system failure or malfunction can be accomplished by the use of a backup system.

(b) For *missiles*, any materiel or installation deficiency requiring identically equipped missiles possessed by the submitting activity to be inspected for the same deficiency will be submitted as a Category I report. If the same deficiency is evident in other missiles, certain restrictions must be imposed to lessen the degree of risk involved.

(c) For *equipment other than aircraft or missile*, materiel, or installation defiencies which require that the affected equipment be withheld from use will be reported as a Category I report. A critical safety deficiency on CEM equipment is any malfunction, design deficiency, or equipment (including safety devices) which could result in exposure of maintenance and operating personnel to lethal voltages, excessive radiation, or other potential danger by either direct or indirect action.

(4) Explosive safety deficiency—A deficiency or condition presenting a known or suspected hazard to personnel and equipment through malfunction, inadvertent functioning, and detonation of ammunition or explosive during use, handling, or storage.

Category II report. The Category II report is a report of:

(1) Non-work unit coded (WUC) items with design and maintenance materiel deficiencies which do not have a safety impact, but the incorrected existence of which would through prolonged usage:

(a) Constitute a hazard.

(b) Have a negative effect on operational efficiency.

(c) Reduce tactical or tactical support ability.

(d) Reduce operational life or general service utilization of equipment.

(e) Create economic burdens (manpower and money). Category II reportable conditions embody degrees of risk or requirements calculated to be tolerable within broad time limits.

(2) Quality deficiencies in materiel which are attributable to nonconformance to applicable specifications, drawings, standards, technical order, errors in workmanship, failure to provide or account for all specific parts, or other conditions that can be traced to nonconformance during manufacture, repair, modification, or maintenance.

Methods of Reporting. Category I reports must be submitted by electrical transmission on DD Form 173, Joint Messageform. These reports will then generate investigation projects which demand the highest priority available at the action and support points, and in the case of grounding action or the removal from service of like items, will require continuous (around the clock) action for resolution.

Category II reports will be submitted by AUTODIN, using Standard Form 368 format to report those deficiencies.

Exercises (650):

1. Give the purpose of the USAF materiel deficiency reporting and investigating system.

2. Match each category given in column B with a corresponding column A statement by placing the number-coded category (column B) beside its letter-coded associated statement (column A). Each item in column B may be used more than once.

	Column A	*Column B*
____	a. Deficiency that could cause a nuclear incident.	1. Category I.
____	b. Uncorrected deficiency reduces tactical support ability.	2. Category II.
____	c. Deficiency creates an economic burden on the unit.	
____	d. Deficiency resulting from errors in workmanship.	
____	e. Inflight deficiency that is not corrected by a backup system.	
____	f. A missile deficiency requiring similar items of equipment be inspected.	
____	g. Deficiency traced to nonconformance during modification.	
____	h. Inadvertent functioning of ammunitions.	
____	i. Deficiency requires that equipment life expectancy estimations be lowered.	
____	j. Deficiency has a negative effect on operational efficiency.	

3. State the method used to report Category I reports.

4. Indicate the method by which Category II reports are transmitted.

651. In specific manner, state how maintenance and inspection reports and charts can be used by supervisors to improve local procedures and, given a hypothetical situation, indicate the records the supervisor has reviewed.

No machinist supervisor can operate effectively without employing and understanding maintenance and inspection reports and charts—our final topic in this chapter and volume.

Maintenance and Inspection Reports and Charts. Maintenance and inspection reports are very important in the life of a supervisor. He has many daily and monthly maintenance reports that can be used to give him an idea of where the workers are being employed and how long they are taking to accomplish various jobs. This information will help him determine where work bottlenecks exist, what areas require extra training to become more efficient, and how to better schedule the various types of jobs. These reports are prepared from information that is supplied on maintenance forms. Besides the maintenance reports that you have on file, the squadron analysis section keeps a complete record of each write-up that is received from the aircraft crewmembers and ground crews. This information is also supplied by maintenance forms.

The job description for the 9-level worker in your career field shows that he is called upon for very difficult tasks. Being widely experienced, however, he will not rush out to the aircraft without first checking the background information on the particular aircraft involved. In fact, if he checks the aircraft history file at the analysis section, he may be able to pinpoint a possible malfunction cause even before going to the aircraft. This resource is often overlooked by the workers. Thus, it is always a good practice to check the past history of an aircraft. Remember, you do not work on every job assigned to the shop.

Charts and graphs are often quite useful to a supervisor as he/she needs to compare several items against each other, such as time versus failures. But a word of caution is called for here; that is, the limitation of the charts or graphs consulted. For one thing, these must never be so complicated in form or appearance that they cannot be read without difficulty in doing so. At the same time, a chart—such as a training chart—*can* contain indication/representation of many training operations, yet still remain readable. However, if the supervisor starts adding to his chart leave schedules, annual shots, and other items that he/she wants to know about his/her people, that supervisor likely cannot, later, determine the training progress involved very quickly. Note, too, that graphs are more limited than are charts. Accordingly, as a general rule, for a graph to be easily readable, it should be limited to not more than five items.

Exercises (651):

1. Cite the reason for a supervisor being interested in the time taken to accomplish a task as shown on maintenance reports.

2. *Situation:* Several mechanics from your shop have worked all night at a troubleshooting problem without locating the trouble. But your supervisor, having reviewed some maintenance records, quickly solves the problem. Identify the records this supervisor probably reviewed.

3. Give the number of graphs normally used to show to their reader 9 items.

Bibliography

Books

Oberg, Erik, and Franklin D. Jones. *Machinery's Handbook,* Nineteenth ed. New York: Industrial Press, 1974.

Colvin, Charles H., Henry F. Colvin, and Eleanor Stanley. *The New American Machinists' Handbook.* New York: McGraw-Hill Book Company, 1973.

Walter, John R. *Modern Metalworking.* Illinois: The Goodheart-Wilcox Company, Inc. 1973.

Department of the Air Force Publications

AFM 39-62, *Noncommissioned Officer and Airman Performance Reports.*

AFM 66-1, *Maintenance Management,* Vols. 1, 2, and 4.

AFM 66-267, *Maintenance Data Collection System.*

AFM 66-278, *Maintenance Management Information and Control System.*

AFM 8-2, *Air Force Technical Order (TO) System.*

AFR 50-23, *On-the-Job Training (PA).*

AFR 127-101, *Ground Accident Prevention Handbook.*

TO 0-1-01, *Numerical Index, Alphabetical Index, and Cross-Reference Table Technical Orders.*

TO 0-5-1, *AF Technical Order System.*

TO 0-5-2, *Technical Order Distribution System.*

TO 00-20-2, *The Maintenance Data Collection System.*

TO 00-20-3, *Maintenance Processing of Reparable Property and Repair Cycle Asset Control System.*

TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating.*

NOTE: None of the items listed in the bibliography above are available through ECI. If you cannot borrow them from local sources, such as your base library or local library, you may request one item at a time on a loan basis from the AU Library, Maxwell AFB, AL 36112, ATTN: ECI Bibliographic Assistant. However, the AU Library generally lends only *books* and a limited number of *AFMs.* TOs, classified publications, and other types of publications are *not* available. Refer to current indexes for the latest revisions of and changes to the official publications listed in the bibliography.

Answers for Exercises

CHAPTER 1

Reference:

600 - 1. The reason is that they are usually readily available and, therefore, reduce both the number of parts to be manufactured and the cost of the item.

600 - 2. This is a triangle (Δ).

600 - 3. Common capscrews have hexagonal heads, while socket head capscrews have round heads, each with a hexagonal socket in it.

600 - 4. This is a flathead screw.

600 - 5. If it was to be used either (1) where the heat could exceed 250° F or (2) in a location that will be subjected to rotational movement.

600 - 6. They are used to connect two parts where it is essential to eliminate any looseness or *play*.

601 - 1. To change a metal's mechanical property or a combination of such properties, so that the metal will be more useful, serviceable, and safe for a definite purpose.

601 - 2. The part could warp or crack.

601 - 3. They affect the rate of cooling of it.

601 - 4. These are internal stresses caused by heat-treatment and the machining operations on the part.

601 - 5. This is a part designed with sharp angles and an uneven balance of mass.

602 - 1. These steps are as follows:
   a. Determine what the tool must do.
   b. Select or invent a device which meets the requirements.
   c. Construct the tool to perform the required task most efficiently.

602 - 2. This is (1) the type of tool needed, (2) the operation it must perform, and (3) how it must be held or fastened to the machine.

602 - 3. To determine whether or not the dimensions of a part are within the specified limits required.

602 - 4. Any of these seven gages: ring, receiving, plug, pin, snap, thread, or form gages.

602 - 5. These are carbon (0.20 percent), manganese (1.00 percent), phosphorus (0.05 percent), and sulphur (0.05 percent).

602 - 6. The reason is that they can be more easily ground after the hardening process.

602 - 7. The reason is that they do not warp or shrink excessively during hardening.

602 - 8. The tolerance for an inspection gage is 10 percent of the tolerance of the part; 10 percent of 0.002 inch = 0.0002 inch. The minimum diameter of the part would be 1.498 inch; therefore, the bore diameter of the gage = 1.498 + .0002 − .0000.

602 - 9. The reason is that working gages usually wear faster than inspection gages.

603 - 1. These are zinc alloys, rubber, thermosetting phenolic, and epoxy plastic.

603 - 2. This is plain carbon steel.

603 - 3. It is prone to be erratic in response to heat-treatment.

603 - 4. It produces very little distortion during heat-treatment and possesses good hardening and wear-resistant qualities. It is used in intricately shaped tools.

603 - 5. This is high-speed tool steel.

603 - 6. They can be made much harder than can tool steels.

604 - 1. The use of the tool because, if the material cannot withstand forces that its intended use will subject it to, it will be of little value.

604 - 2. The tool materials should be hard enough and wear resistant (tough) enough to enable it to withstand the abrasive wear to which it will be subjected.

604 - 3. The problems of tool deflection and thermal expansion will most likely increase greatly.

604 - 4. First, make a list of the materials, parts, tools, and machining operations that will be required, the reason being to insure that the job will be economically, accurately, and timely.

604 - 5. The reason is that usually one of the machines will perform the operation better, quicker, and with less trouble than will the other two, which would mean a savings of time and money.

604 - 6. Where possible, arrange the machining operations so that all like operations can be completed at the same time. This cuts down the machine setup time.

605 - 1. It normally incloses all or a large portion of the part to be machined. It is supported on the side opposite the drill surface with four feet or legs and is usually provided with a leaf cover that is either hinged or swiveled away for loading.

605 - 2. a. 9
   b. 7
   c. 1
   d. 6
   e. 2
   f. 3, 5
   g. 10

606 - 1. a. 3, 7
   b. 1, 5
   c. 1
   d. 2, 6
   e. 4

606 - 2. This is determined by the type of jig they will be used on and the way in which they must perform.

607 - 1. They are designed to hold specific shapes of work and they replace the standard vise jaws, usually only the stationary jaw. They locate and support the work while the standard movable vise jaw clamps the part in place.

607 - 2. This is the angle plate fixture.

607 - 3. They are used to hold more than one like part, so that, as one is being machined, the other can be removed and another unmachined part mounted.

608 - 1. The reason is that the welded type is more rigid, it can be easily modified, and when it must be machined after welding, it is usually more accurate.

608 - 2. The cast type is formed into the shape required; whereas the one-piece type is machined into the required shape from a solid piece of material.

608 - 3. The reason is that the cost of manufacturing it is usually excessive.

608 - 4. There are three primary axes about which a part can be moved or rotated. It can be moved either in a linear or rotational direction for each axis. Therefore, there are three linear movements and three rotational movements that make up the six elementary movements.

608 - 5. *Three locators* are fixed to the base of the jig or fixture to prevent the part from rocking; *two locators* are placed on one of the vertical side members to prevent movement in one direction and to prevent rotation; and *one locator* is placed on an end vertical member to prevent movement in another direction and complete the location of the part.

609 - 1. Any rest buttons more than the three primary ones should be adjustable to make up for slight imperfections that might still be present in the surface.

609 - 2. The locators (three should be positioned as far apart as possible to minimize the position variation of different parts.

609 - 3. These are: (1) lengthwise movement and (2) rotational movement.

609 - 4. Conical locators automatically make up for any variation in the diameter of the hole into which they fit.

610 - 1. In the blanking operation, the punched-out part is saved; whereas, in the piercing operation, the punched-out part is scrap.

610 - 2. The metal is forced to *flow* into another shape, such as a cup, shell, box, etc.

610 - 3. *Coining* is used to produce letters or markings in relief on the material.

610 - 4. *Ironing* is the process of reducing the wall thickness of an item without changing the thickness of the bottom surface. It is accomplished by forcing the part through a die in which the clearance between the die and punch is less than the thickness of the metal part.

610 - 5. These are: (1) the punch holder and (2) the die shoe.

610 - 6. This is the back-pin set that has the pins located at the back, leaving the front and sides clear for hand-feeding the blanks.

610 - 7. The direction from which the designer intends that the blank should be fed determines this.

610 - 8. Choose the four-pin type.

611 - 1. The possibility of bending the blank is decreased; the blanks can be removed as they are cut by using knockout pin; and the cutting edges remain free of chips, which allows them to last longer.

611 - 2. Piercing operations should be first; blanking operations in one or more stages, as required, should be next; and bending or forming operations should be last.

611 - 3. The blanking die, which is fitted with the piercing punches, is mounted in the die head; and the piercing dies are drilled or formed into the blanking punch, which is mounted in the die shoe.

611 - 4. Material pieces that would have to be discarded when using a progressive die can many times be hand-fed into a compound die in such a way as to obtain one or more extra blanks.

612 - 1. The best location of the blanks to save material and the best location to secure good bending when bending is required are these factors.

612 - 2. Consider whether or not the extra cost of labor outweights the savings in material.

612 - 3. Many times the blanks can be staggered on the wider stock in such a way that it produces almost twice as many pieces as it does on two narrower strips.

612 - 4. The importance lies in the fact that if any bends are to be made in the blanks, the blanks should be arranged on the stock so that the bends will be across the grain or at no less than a 45° angle to it.

612 - 5. As the stock passes forward through the die, the pawl raises and rides over the scrap portion of the stock until it (the pawl) falls into the hole left by the previous blanking operation. Then the stock is pulled back until it contacts the pawl again, which stops the work in the proper location for the next blanking operation.

613 - 1. Strippers are used to remove stock from a punch after a blanking or piercing operation.

613 - 2. The pressure pad holds the work in place as the punch passes through it and, in many cases, serves as a stripper on the upstroke of the punch.

613 - 3. This is the channel-type, either of the one- or the two-piece variety.

613 - 4. These are Allen type bolts; they are adjusted by placing spacers under the shoulder of the bolthead.

613 - 5. The purpose is to prevent the spring from cocking and breaking.

614 - 1. This is done either (1) by designating the space between the punch and the die on only one side or (2) by designating the total difference between the sizes of the punch and the die.

614 - 2. The normal requirement is 5 to 6 percent of the stock's thickness.

614 - 3. The relief is required below the cutting edge of the blanking die.

614 - 4. This relief varies from 1/4° to 2°.

614 - 5. It is a straight area approximately 1/8 inch wide just below the cutting edge of the die.

614 - 6. It provides added cutting edge support for cutting harder materials and allows the die to be sharpened without changing the size of the die cavity.

615 - 1. The perimeter of the blank = 0.825 × 4 = 3.3 inches; therefore, the die block should be 1 inch thick.

615 - 2. Add 2½ inches to the length and width of the part to be manufactured.

615 - 3. Blanking pressure = length of cut times material thickness times tensile strength; blanking pressure = $(\pi \times 4) \times 0.125 \times 50{,}000$; blanking pressure = $12.5664 \times 0.125 \times 50{,}000$; blanking pressure = $1.5708 \times 50{,}000$; blanking pressure = 78540 pounds.

615 - 4. Apply a shear angle to the punch.

616 - 1. The punch should receive the clearance.

616 - 2. It must be subtracted from the size of the punch.

616 - 3. The purpose is to keep the edges of the hole from cutting into the perimeter of the die opening or of the punch and to permit the traces of the hole to be filed away after the sawing operation.

616 - 4. The saw kerf should be inside of the layout line for the die opening and outside the perimeter of the punch at the bottom of the cut.

617 - 1. You wish to determine the cause of any defects that might be present in the design and machining of the assembly.

617 - 2. Causes can be any of these: incorrect die clearance, too small a press, or a punch and die shoe out of alignment.

617 - 3. Do this by polishing both the die and the punch mating surfaces.

CHAPTER 2

618 - 1. The TO system insures performance of our mission with the greatest possibility for success and the least chance for loss of life or damage to equipment.

618 - 2. They provide technical information and instructions to operate, install, maintain, inspect, or modify Air Force systems and equipment items.

618 - 3. AFR 8-2, *Air Force Technical Order (TO) System*.

619 - 1. It is a list of applicable publications and an index-type technical order.
619 - 2. You would consult a depot level technical manual.
619 - 3. These are: Immediate Action, Urgent Action, and Routine Action.
619 - 4. Urgent Action TCTOs.
619 - 5. a. 3
  b. 5
  c. 7
  d. 2, 6
  e. 1
  f. 4

620 - 1. The category designation is the first part.
620 - 2. The second part indicates an equipment type or model.
620 - 3. a. TCTO.
  b. Index.
  c. Abbreviated TO—checklist.

621 - 1. Whereas a change effects only small parts of TOs, a revision is issued when a change effects more than 80 percent of the TO, and it changes the basic date of the TO.
621 - 2. Check the title page of the change to see whether or not the supplements have been included or are to be retained.
621 - 3. Look at the title page of the revision.
621 - 4. A cumulative supplement includes and replaces all previous supplements; whereas the noncumulative does not do this.
621 - 5. See whether an SS or an S follows the TO number. When an SS is added, a safety supplement is indicated. In contrast, when a single S appears, an operational supplement is indicated.
621 - 6. File them in the TO but in reverse numerical order.
621 - 7. The reason is that the appendix was issued later than the TO and contains additional new information than that referenced on the title page.
621 - 8. Keep it until the TO is listed in the NI&RT as rescinded.

622 - 1. TO 0-1-01.
622 - 2. It contains the Air Logistic Center (ALC) that is responsible for storing and issuing the index, and it is listed by an alpha code.
622 - 3. You use them to determine the availability and status of publications for requisitioning TOs and maintaining the files.
622 - 4. When you know the type of equipment but not the number or category.
622 - 5. By consulting the appropriate LOAP, you can determine this.

623 - 1. This is 0-1-34.
623 - 2. Check the title page for the class of equipment, and then turn to the indicated page to find the TO covering the specific piece of equipment.
623 - 3. Do this because the alphabetical index is not always kept as current as the 0-1-01.
623 - 4. Check in TO 0-4-2.

624 - 1. Fill out an AFTO Form 22, Technical Order System Publication Improvement Report and Reply.
624 - 2. Consult TO 00-5-1, *AF Technical Order System*.
624 - 3. Do this when a TO deficiency is found that, if uncorrected, would result in fatal or serious injury, destruction or extensive damage to equipment or property, or inability to maintain operational mission posture.
624 - 4. Expect a reply within 60 days.

625 - 1. The area containing the mathematical tables is normally used most.
625 - 2. You can find in it the setup procedures and the necessary formulas for end-gearing and gear-cutting calculations.
625 - 3. Turn to the index in the back of the book.
625 - 4. Manufacturer's service manuals will likely concern you most.
625 - 5. Check the NI&RT for the category of equipment to see whether or not it has had a number assigned. If not, you should consult TO 00-5-1 for procedures for obtaining a number.
625 - 6. You can sometimes learn special operator techniques and you can learn construction and design information that will help you operate and maintain the equipment more efficiently.

CHAPTER 3

626 - 1. Coordination is required in order to prevent confusion among the work force and to accomplish the work in a timely manner.
626 - 2. Job control has this task.
626 - 3. He must do this in order to achieve a well-balanced, smoothly operating organization.

627 - 1. These are: manpower and equipment.
627 - 2. The reason is to insure that personnel are available for high priority work when it is required and that it is accomplished before lower priority work when they both cannot be done at the same time.
627 - 3. You must consider (1) the number of people required to be available for regular and unscheduled work; (2) the training requirements for the job; (3) appointments, details, etc., that will distract from your work force; and (4) leave schedules and requests from your personnel.

628 - 1. Consider these: the skill level and experience of the workers involved, the priority of the job, and the work distribution requirements.
628 - 2. A person may have the skill level to qualify him to do a certain job, but if he has never done the job before, he may not be able to do it as fast as a person with a lower skill level who has experience on that job.
628 - 3. Send the experienced 5 level to remove the broken stud, and send the 3 level out with the newly assigned 5 level to remove the screws from the wing.

629 - 1. He should review the work thoroughly, stressing the strong and weak points. He should not tolerate poor workmanship, and he should praise skillfully done work.
629 - 2. He did not make an in-progress inspection. Had some part of the job been done in error, the assembly could have been damaged during the operational check. Also, he did not inspect the job before the operational check.

630 - 1. He must establish performance standards to insure that the quality of work remains high and in order to judge established work methods.
630 - 2. When the person being corrected first allowed his hair to become too long, he was not meeting an established standard. Now, if it is allowed to go uncorrected, it will encourage him to lower another standard.
630 - 3. He is failing to control and enforce the standards.
630 - 4. The workers will be more interested in their work.

631 - 1. The purpose is to select the best airman for promotion.
631 - 2. These are when the reporting official is changed or to remove an individual from the control roster.
631 - 3. No, you are not so required.
631 - 4. Refer to AFM 39-62, *Noncommissioned Officer and Airman Performance Reports*.
631 - 5. The reason is that the notification may not give the supervisor enough time to accurately and fairly evaluate and write the report.

632 - 1. It is a tool used to control the quality and effectiveness of formal and career development courses.
632 - 2. These are: (1) field evaluation visits, (2) direct correspondence questionnaires, (3) job performance evaluations, and (4) CDC trainee questionnaires.

632 - 3. They are used to ask recent graduates of formal schools and their supervisor about the effectiveness of the training the graduate has received in comparison with the duties he must perform, and these answer cards must be handled carefully because they are scanned by a computer, and a damaged card could be scanned inaccurately or rejected.

632 - 4. These are: If a supervisor determines that a graduate has been undertrained or overtrained on the proficiency levels established by the STS. Also, if the STS code levels exceed the requirements of the AFS.

633 - 1. He should go to you.

633 - 2. Research applicable publications to find the answer.

633 - 3. It is to assure your people that *their* problems are *your* problems, too, and as a result, to increase worker confidence in you.

633 - 4. The worker should be informed of what is expected of him and of ways he can improve his work. He should be praised publically and admonished in private.

633 - 5. These are: (1) continue to look for that extra ability that may not be in use and (2) never stand in an individual's way as he seeks to develop his abilities.

633 - 6. These are: (1) get the facts, (2) weigh them and decide, (3) take action, and (4) check the results.

633 - 7. Ask yourself "How soon should I follow up, and how often will I need to check to be able to evaluate any changes in output, relationships and attitudes?" Also, "Have my actions produced the desired results?"

634 - 1. These are: (1) on-the-job trainer, (2) equipment manager, (3) shift supervisor, (4) safety supervisor, (5) team chief, and (6) assistant shop supervisor.

634 - 2. Make it the largest position on the chart, with your immediate supervisor's position *above* it and your subordinates *below* it.

634 - 3. It serves as a quick reference of the duties and responsibilities that a given position carries with it.

635 - 1. These are: (1) removed, replaced, or modified systems; (2) overtime requirements; (3) mission requirements; and (4) TDY assignments.

635 - 2. He may (1) make an emergency manpower request or may (2) reassign some of the work overload to another section.

635 - 3. He wants to be sure that he has all of the necessary information clearly in his mind before going to higher commands for help.

636 - 1. These are: (1) detailed planning, (2) careful scheduling, (3) timely implementation, (4) capable direction, (5) skillful application, and (6) continuous evaluation.

636 - 2. This is a failure to establish an effective OJT program.

636 - 3. They are: (1) to provide upgrade training (UGT) or (2) to provide qualification training (QT) for subordinates.

636 - 4. This is training accomplished by developing an individual's job knowledge and his job proficiency.

636 - 5. This is the USAF Specialty Training Standard (STS).

636 - 6. The CDC provides the job and career knowledge portion of the *dual channel concept* as applied to UGT.

636 - 7. Qualification training (QT) is used to train a person on a specific task and does not involve any increase in skill level. It does not require the use of CDCs and has no official time limit other than that established by the supervisor involved.

637 - 1. It provides the individual with actual job experience.

637 - 2. This is required when an airman is given a directed duty assignment (DDA).

637 - 3. This can occur when a 3-level airman is in paygrade E-5, is in a career ladder that does not have a 5-level position, and a training capability exists.

637 - 4. You would document this as qualification training.

637 - 5. It would usually be conducted within the unit to which the trainee is assigned and on actual tasks being performed by the unit.

638 - 1. This responsibility belongs to the commander.

638 - 2. Commanders at all levels must insure this.

638 - 3. It is responsible for validating and forwarding mandatory CDC applications to ECI and for administering course examinations.

638 - 4. The squadron OJT administrator has this responsibility.

638 - 5. This responsibility belongs to the squadron OJT administrator, too.

638 - 6. AFM 50-23, *On-the-Job Training*, contains this information.

638 - 7. The immediate supervisor does this.

638 - 8. He has this responsibility when the immediate supervisor and the trainer are one and the same person.

638 - 9. You can give them meaningful jobs whenever possible.

639 - 1. Administer aptitude tests.

639 - 2. Maintain an awareness of the status of the training program.

639 - 3. The trainees become more competent, and the trainer has the satisfaction of knowing his efforts have been effective in making a productive worker of the trainee.

639 - 4. Going from the known to the unknown.

639 - 5. Combine it with one or more of the other training methods.

639 - 6. It promotes a two-way exchange of ideas.

639 - 7. The demonstration method is best in these circumstances.

639 - 8. The performance method is the most effective.

639 - 9. He did not prepare the training situation.

639 - 10. He did not follow up. He should have checked the trainee's work every few minutes and also checked to see that the trainee followed established safety practices.

640 - 1. The trainee can learn complex jobs one step at a time and, by making a job breakdown, the trainer isn't as likely to overlook the small seemingly insignificant steps that are important to the trainee.

640 - 2. The Important Steps section should include the commonsense step-by-step points that must be done to complete the job; whereas the Key Points section includes safety warnings, *make* or *break* action reminders.

640 - 3. You should first carefully watch someone else perform the job who is more experienced or expert at the job than you.

641 - 1. Training records are often used as determining factors in deciding award or withdrawal of AFSCs, entry into or withdrawal from OJT status, and selectivity for preferred assignments.

641 - 2. Include the appropriate Job Proficiency Guide (JPG).

641 - 3. The immediate supervisor does this.

641 - 4. The training source of the trainee is the determinant; once OJT for upgrading is completed, the forms should be removed.

641 - 5. AFM 50-23, *On-The-Job Training*, outlines this.

641 - 6. It is a continuation sheet for the various sections of the AF Form 623.

641 - 7. The STS is a detailed breakdown of a particular career field based on the applicable AF specialty description in AFM 39-1. In contrast, the JPG is an STS on which the actual taskes that the trainee will be required to do have been annotated.

641 - 8. You should do this on AF Form 797.

CHAPTER 4

642 - 1. He must manage the maintenance complex by planning, scheduling, controlling, and directing the use of maintenance resources to accomplish the mission.

642 - 2. The DCM is responsible for the quality and timeliness of maintenance performed on assigned equipment; therefore, if your work as a machinist is substandard, it will distract from the DCM's ability to successfully accomplish his job.

642 - 3. He is responsible for insuring that an effective safety program is established and adhered to within the maintenance complex and for insuring that competent training programs are established.

643 - 1. These are: (1) maintenance control and (2) quality control.

643 - 2. (1) Job control, (2) plans and scheduling and documentation, and (3) materiel control are these divisions.

643 - 3. a. 2, 5
b. 1
c. 3, 4

643 - 4. Quality control manages this program.

643 - 5. (1) Administration, (2) production analysis, (3) training management, and (4) programs and mobility belong to this group.

643 - 6. It analyzes maintenance data reports to identify trends or weaknesses in work centers, equipment, maintenance practices or management actions. Its people can furnish the supervisor with information concerning his man-hour utilization, trends in type of work performed, and time spent on various types of work.

643 - 7. Programs and mobility has this responsibility.

644 - 1. The intermediate level is your level.

644 - 2. You would work at the depot level.

644 - 3. The reason is that aircraft are assigned to OMS, and in the Air Force, the owning organization is assessed with the responsibility for the upkeep.

645 - 1. Its purpose is to provide for recording, processing into report form, and disseminating information on maintenance actions for use by supervisors and managers at all levels.

645 - 2. This is done through daily and monthly reports.

645 - 3. It is used to:
a. Identify equipment configuration.
b. Assure accomplishment of TCTOs.
c. Project workload and scheduling requirements.
d. Provide mechanized historical records for designated equipment.
e. Provide accurate configuration status for high cost or mission significant items.

645 - 4. He uses the (1) Maintenance Personnel Listing and the (2) Monthly Man-hour Summary for this purpose.

645 - 5. It is obtained from MDC forms turned in by each work center during the month.

645 - 6. The number of people authorized for his work center is largely based on how much nonproductive or undocumented time is expended, and the accomplishment of the shop mission will suffer if the percentage of nonproductive labor is allowed to remain too high.

645 - 7. This is done with special codes, which are listed in TO 00-20-2 and aircraft and equipment code manuals (-06 technical orders).

646 - 1. These are: (1) the AFTO Form 349, Maintenance Data Collection Record, and (2) the AFTO Form 350, Reparable Item Processing Tag.

646 - 2. It is used for both (1) documenting personnel actions on equipment end items and (2) recording productive-indirect labor time.

646 - 3. TO 00-20-2 and the related 00-20-2 series TOs do this.

646 - 4. The 195 means the 195th day of the year, and the 0002 means the 2nd job of the day or reporting period.

646 - 5. This is the equipment classification code.

646 - 6. This code identifies a specific type of aircraft, equipment, or specific type of work in support of that equipment.

646 - 7. TO 00-20-2 has this list.

646 - 8. The second character of the identification number is the first character or prefix of the equipment classification code.

646 - 9. It is a one digit number that identifies the position of an engine on an aircraft when work is performed on an engine or component parts.

646 - 10. The labor category code is used here for this purpose.

646 - 11. AFM 300-4 and the applicable equipment -06 code manuals do this.

646 - 12. The top part of the AFTO Form 350 is a routing tag that is attached to equipment components as they go through the maintenance shops for repair. It is also the source document for filling out the AFTO Form 349 for work done on that equipment. The bottom part of the tag is used by the production control activity to keep a running record of the equipment status as it is being repaired.

647 - 1. The Reparable Processing Center (RPC) or Reparable Assets Control Center (RACC) does this.

647 - 2. It means "due in from maintenance" and is used to identify high value or limited availability items which must be returned to Supply after processing through the maintenance shops.

647 - 3. This is AWM, which means awaiting maintenance.

647 - 4. It means *awaiting parts*, and it is used when repairs on an item must be halted until an ordered part is issued by Supply.

647 - 5. Return the gear box to Supply as an NRTS item, using the applicable NRTS code.

648 - 1. The purpose is to locate and repair equipment defects and their causes before they produce major damage or component failure.

648 - 2. These are: (1) the preinspection phase, (2) the look phase, (3) the fix phase, and (4) the postinspection phase.

648 - 3. It is the postinspection or followup phase.

648 - 4. It has developed the -6 technical orders, which list all of the items to be checked.

649 - 1. The authorized concepts are the (1) periodic, (2) phased, and (3) isochronal.

649 - 2. The *basic postflight* is conducted after each flight to determine whether or not the aircraft is suitable for another flight. In contrast, the *hourly postflight* is not conducted after each flight but rather after the flight in which a specified number of flying hours was accumulated. It is also a more in-depth inspection than is the basic postflight.

649 - 3. These are the: (1) preflight, (2) thru-flight, (3) basic postflight, (4) hourly postflight, and (5) periodic inspections.

649 - 4. This is the isochronal concept.

650 - 1. It is to establish data feedback methods to responsible activities so that action can be initiated to correct and prevent materiel, design, and quality deficiencies.

650 - 2. a. 1
b. 2
c. 2
d. 2
e. 1
f. 1
g. 2
h. 1
i. 1
j. 2

650 - 3. They are transmitted electronically using DD Form 173.

650 - 4. They are transmitted by AUTODIN using Standard Form 368.

651 - 1. The reason for the supervisor being interested here is to permit him to identify work bottlenecks and training requirements within his shop.

651 - 2. He likely reviewed the aircraft history file.

651 - 3. Two graphs.

AU GAFS,AL(831822)900

STOP-

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 2 PENCIL ONLY.

53150 04 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

TOOL DESIGN AND SHOP MANAGEMENT

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover your answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if a all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

BEST COPY AVAILABLE

Multiple Choice

Note to Student. Consider all choices carefully and select the best answer to each question.

1. (600) What marking on the head of an aircraft bolt identifies it as a close tolerance bolt?

a. An 'X'.	c. A double dash.
b. A dash.	d. A triangle.

2. (601) The improper design or heat-treatment of a part may cause the part to

   a. crack or warp badly.
   b. cool too slowly and prevent it from hardening.
   c. shrink below acceptable limits.
   d. do all of the above.

3. (602) All of the following are steps involved in tool planning except

   a. fabricating the nonstandard parts as required.
   b. determining what the tool must do.
   c. selecting or inventing a device to meet the requirements.
   d. constructing the device to perform most efficiently.

4. (602) When designing both working and inspection sets of ring gages, the working gages should have

   a. less total tolerance than the inspection set.
   b. 10 percent more total tolerance than the inspection set.
   c. the same total tolerance as the inspection set.
   d. slightly more total tolerance that the inspection set.

5. (603) The most widely used material in the manufacture of punch and die sets is

a. tungsten carbide.	c. plain carbon steel.
b. highspeed tool steel.	d. nondeforming tool steel.

6. (604) The main factor to be considered in selecting the material for a special tool is the

   a. type of machine the tool will be used on.
   b. minimum deflection force that the tool will encounter.
   c. intended use of the tool.
   d. amount of wear to which the tool will be subjected.

7. (604) To ensure that a tool is manufactured accurately and economically, you should

   a. first make a list of the tools, parts, materials, and operations that will be required.
   b. do the drill press work first, the lathe work second, and the grinding work last.
   c. do the lathe work first, the drill press work second, and the grinding work last.
   d. first make a diagram of the arrangement of the machines in the shop and decide on the order in which you will use them.

BEST COPY AVAILABLE

8. (605) The type of drill jig that is especially adaptable for locating and drilling holes for setscrews in pulleys, collars and gears is the

   a. closed or box jig.
   b. template jig.
   c. plate jig.
   d. angle plate jig.

9. (605) The combination type drill jig is designed to be used when

   a. more than one part is to be drilled at the same time.
   b. the part is symmetrical and can be placed in the jig in more than one position.
   c. parts of various sizes and shapes must be drilled.
   d. more than one kind of operation is to be performed on the same hole.

10. (606) A type of jig drill bushing that not only guides the drill bit but also eliminates the need for other holding devices is the

   a. press fit type.
   b. slip renewable type.
   c. screw type.
   d. fixed renewable type.

11. (606) Which of the following types of jig drill bushings is put mainly in jigs that are used for one kind of machining operation and for limited production?

   a. Press fit.
   b. Fixed renewable.
   c. Screw.
   d. Special.

12. (607) In auxiliary vise jaw types of milling fixtures, the auxiliary jaws

   a. normally replace both the stationary and movable standard vise jaws.
   b. are usually just placed in front of the standard vise jaws.
   c. replace only the movable standard vise jaw.
   d. normally replace the standard stationary vise jaw only.

13. (607) Duplex milling fixtures are especially designed to hold two like parts in such a way that

   a. both parts can be machined at the same time.
   b. the milling cutter will cut both parts during the same pass.
   c. more than one type of machining operation can be done at the same time.
   d. as one part is completed, it can be removed while another part is being machined.

14. (608) Which of the following types jig and fixture body construction should normally be avoided because of the cost of construction?

   a. One piece type.
   b. Welded type.
   c. Three piece type.
   d. Builtup type.

15. (608) The use of six rest buttons (locators) arranged in a specific pattern in a jig or fixture is known as the

   a. 1-2-3 principle of location.
   b. 1-4-1 principle of location.
   c. 321 principle of location.
   d. 33 principle of location.

16. (609) You must position locators in a fixture to support parts with rough surfaces. To minimize the possible difference in the position of the parts, you should

a. align the locators in a straight line.
b. keep the locators close together.
c. keep the locators as far apart as possible.
d. move the locators to suit each part.

17. (609) In jig and fixture work, which of the following are more adaptable than cylindrical locators?

a. Internal locators.
b. V-locators.
c. Conical locators.
d. Mounting locators.

18. (610) A punch and die operation in which the punched out part is discarded as scrap is called

a. blanking.
b. piercing.
c. drawing.
d. forming.

19. (610) The type of die set that provides maximum rigidity and accuracy of alignment, but which is dangerous for hand-feeding the stock is the

a. four-pin type.
b. round-die type.
c. center-pin type.
d. diagonal-pin type.

20. (612) The shoulder stop is the most effective type of mechanism for locating the stock in which of the following die operations?

a. In a progressive die where the blank is at least 1/2 the width of the stock and is centered.
b. In a compound die where the blank is twice the width of the stock.
c. In a progressive die where the blank is the entire width of the stock and the last step is a cutoff operation.
d. In an inverted die where the blank is at least 1/2 the width of the stock.

21. (613) In a punch and die set, a stripper can be used to

a. part the stock off after a blanking operation.
b. remove the stock from the punch.
c. cut the stock into long narrow strips.
d. support the work as the die passes through it.

22. (614) In a blanking or piercing operation, if too much clearance is provided between the punch and die, the

a. blank will be undersized.
b. punch will move around in the die causing inaccurate work.
c. blank will have ragged or burred edges.
d. punch will not be able to pass through the die.

23. (615) When manufacturing a die for punching round blanks, the minimum margin around the die opening should be

a. 7/8 inch.
b. 1 1/4 inches.
c. 2 1/2 inches.
d. 3 inches.

BEST COPY AVAILABLE

24. (616) In the contour sawing of dies, the starting hole should be drilled

a. at an angle that varies with the thickness of the material.
b. at a right angle to the die surface.
c. in the center of the punch blank and not in the die blank.
d. at the same angle as the saw cut.

25. (617) In a functional tryout of a blanking die, you find that the punch does not complete the operation. A probable cause is

a. an incorrect die clearance.
b. an improper punch and die alignment.
c. too small a press.
d. all of the above.

26. (618) Air Force technical orders are published and distributed under the authority of the Secretary of the Air Force by

a. Headquarters, USAF.
b. the Air Force Logistics Command.
c. the Strategic Air Command.
d. the Air Training Command.

27. (619) All of the following are types of technical orders except

a. indexes.
b. automation.
c. expanded.
d. abbreviated.

28. (619) A type time compliance technical order (TCTO) that has alternating red diagonals and circled red Xs on the first page is the

a. Immediate Action TCTO.
b. Urgent Action TCTO.
c. Routine Action TCTO.
d. Quick Response TCTO.

29. (620) The first part of a technical order number is the category that the TO is part of. What number designates the methods and procedures TOs?

a. 00.
b. 0.
c. 1.
d. 66.

30. (620) Which of the following technical orders is considered to be a technical manual?

a. 00-5-1.
b. 0-1-34.
c. 1B-47-1200.
d. 34C2-8-3-1.

31. (621) If you must file a change in a technical order and notice that the date of the change is later than the date of the latest supplement, then you should

a. check the title page of the supplement.
b. leave the supplement in the TO.
c. remove the supplement from the TO.
d. check the title page of the TO.

BEST COPY AVAILABLE

32. (621) You have just received a TO supplement with the number 1F-106-A-1-S-2. This is

a. a safety supplement.
b. an operational supplement.
c. an urgent action supplement.
d. a routine supplement.

33. (622) Which of the following numbers identifies the 'index of indexes' and contains a list of NI&RTs?

a. 0-0-1.
b. 0-01-1.
c. 0-1-01.
d. 0-1-34.

34. (622) Which type of TO index should you consult to find the applicable data code for a certain TCTO number?

a. A cross-reference table index.
b. An applicable LOAP.
c. A numerical index and requirement table.
d. An alphabetical index.

35. (623) You must locate information on a specific piece of equipment and you have located the applicable TO category in TO 0-1-01. What is your next step?

a. Consult the table of contents of TO 0-1-01.
b. Search through the TOs within that category.
c. Consult the numerical index applicable to that category.
d. Consult the alphabetical index for that equipment.

36. (623) Which of the following TO indexes can not be used to requisition technical publications?

a. TO 0-1-01, index of indexes.
b. TO 0-1-32, NI&RT.
c. TO 0-1-34, index to category 34 TOs.
d. TO 0-2-1, alphabetical index.

37. (624) When you fill out an AFTO Form 22, Technical Order System Publication Improvement Report and Reply, on a TO deficiency that requires an Urgent category report, the deficiency should be one that

a. would result in destruction of equipment if not corrected.
b. could prevent safe mission accomplishment if not corrected.
c. would negatively effect maintenance efficiency if not corrected.
d. could result in fatal or serious injury if not corrected.

38. (624) Once you have submitted an Urgent report AFTO Form 22, the activity responsible for corrective action must reply within

a. 30 work days if the report is approved.
b. 30 calendar days unless the report is disapproved or downgraded.
c. 30 calendar days if the report is disapproved or downgraded.
d. 20 calendar days if the action will be completed in 30 days.

BEST COPY AVAILABLE

39. (625) Probably the most used portion of the Machinery's Handbook or a similar publication is the area containing

a. the formulas for cutting helical gears.
b. information on grinding wheels.
c. information on the strength of materials.
d. the mathematical tables.

40. (625) What is the best way to locate specific items of information in the Machinery's Handbook or similar publications?

a. Look in the index in the front of the book.
b. Thumb through the pages.
c. Look in the table of contents in the front of the book.
d. Look in the index in the back of the book.

41. (625) A manufacturer's service manual for a piece of shop machinery should have a

a. locally assigned number after the title on the cover page.
b. TO identification number stamped in the lower left-hand corner.
c. TO identification number stamped in the upper right-hand corner.
d. locally assigned TO number stamped in the upper right-hand corner.

42. (626) Four specialists from two different shops were all dispatched to work on an aircraft engine at the same time, but, when they arrived at the aircraft, they found specialists from the engine shop removing the engine. What was most probably the cause of the trouble?

a. A lack of coordination.
b. Shop supervisor reacting too quickly.
c. Poor work organization by engine shop.
d. Engine shop personnel working too slowly.

43. (627) Ensuring that highly skilled individuals are assigned the more difficult tasks and that less skilled individuals are not assigned tasks beyond their capabilities is an example of

a. effective work assignment.
b. effective scheduling of resources.
c. the proper use of the skills of assigned personnel.
d. all of the above.

44. (628) As the shop supervisor, you must dispatch someone to accomplish a difficult, high priority job similar to the jobs your shop has done several times in the past. You have two people available; a 5 level who has worked for you for over 1 year and a newly assigned 5 level who is in 7 level training. Both are good workers. Who should you send to do the job?

a. Both of them.
b. Try to find out which one wants to do the job and send him.
c. The 5 level who has a year's experience on such jobs.
d. The 5 level who is studying for the higher skill level.

45. (628) Failure to distribute the work equally as far as possible based on job priorities and workload requirements would most likely result in

a. hard feelings.
b. unhappy workers.
c. poor quality workmanship.
d. All of the above.

46. (629) Besides ensuring quality workmanship by shop personnel, a thorough check of completed work can be used by the supervisor as

a. an excellent learning device for a man in training.
b. an excellent opportunity to point out the worker's faults.
c. an opportunity for criticizing a worker who has been causing trouble.
d. a means of instilling the desire for perfection in the workers.

47. (630) A shop supervisor should establish and set performance standards that can be met by

a. his best workers.
b. his worst workers.
c. all of his assigned personnel.
d. most of his assigned personnel.

48. (630) As supervisor, you have established performance standards for your personnel, but you notice that a certain area has been falling below standard. What should you do?

a. Make an example the individual who has not been meeting the standard.
b. Gradually increase control of the area and set new standards.
c. Slowly ease the area back to the required standard.
d. Take immediate measures to get it back to standard.

49. (632) The purpose of the USAF Graduate Evaluation Program is to

a. control the quality and effectiveness of OJT programs.
b. determine if a CDC student is knowledgeable enough to take the course examination.
c. determine if a formal school student is qualified to graduate.
d. control the quality and effectiveness of formal and career development courses.

50. (632) In the USAF Graduate Evaluation Program, the evaluation method that is least desirable because of the time and expense involved is the

a. job performance evaluation.
b. direct correspondence questionnaire.
c. CDC trainee questionnaire.
d. field evaluation visits.

51. (633) A good way of increasing a worker's confidence in you as supervisor when he approaches you with a technical problem that you can't answer is to

a. make him feel that he should have known the answer so he won't ask you again.
b. give him a generalized solution and let him find the specific answer.
c. tell him you're busy and tell him to find out by researching the answer.
d. tell him you don't know, but you will research the answer.

52. (633) The first step in handling a problem encountered by one of your subordinates is to get the facts. Next, you must weigh those facts and decide on a course of action. Which of the following examples are substeps under the 'weigh and decide' step?

a. Be sure you have the complete story.
b. Get opinions and feelings.
c. Fit all the facts together.
d. Talk with the individual concerned.

53. (634) A type of chart that the shop supervisor can develop to show the duties and responsibilities of each position within his organization is

a. a position chart.
b. an organizational chart.
c. a flow chart.
d. a functional chart.

54. (635) If you were a shop supervisor, which of the following situations would most likely justify an increase in your manning authorization?

a. Subordinates tend to take too long to accomplish simple tasks.
b. Subordinates continually produce poor quality work.
c. Several subordinates are on leave and you can't meet mission requirements.
d. Subordinates must continually work overtime to meet workload demands.

55. (636) Satisfactory completion of an applicable career development course is required when OJT is conducted for the purpose of

a. upgrade training (UGT).
b. job proficiency training (JPT).
c. job proficiency guidance (JPG).
d. qualification training (QT).

56. (636) Qualification training is conducted for individuals who have already been upgraded, but who require training on

a. specific items of the job on which he had not been previously trained.
b. a new piece of equipment that has been installed in the shop.
c. the operation of a piece of AGE that he will be using.
d. all of the above.

57. (637) A 3 level machinist may be awarded the 5 skill level after

a. completing an OJT program.
b. obtaining a qualifying score on the bypass specialist test.
c. completing a formal training school.
d. all of the above.

58. (637) When the only input to a career ladder is from another related career field at a certain skill level, the training requirement to progress into that career ladder is called

a. qualification training.
b. on-the-job retraining.
c. lateral training.
d. proficiency training.

59. (638) Within a squadron, who is charged with the overall responsibility for OJT?

a. The commander.
b. The immediate supervisor.
c. The shop supervisor.
d. The squadron OJT administrator.

60. (638) An immediate supervisor is responsible for preparing detailed task breakdowns for the trainee only when the

a. immediate supervisor and the trainer are the same person.
b. immediate supervisor is also the shop supervisor.
c. immediate supervisor thinks they would be helpful.
d. trainee is having trouble progressing in training.

61. (640) The best way to effectively break down a job with which you have had little experiznce is to

a. first carefully watch the motions used by someone more expert in the job than you.
b. make the job breakdown during the training session.
c. do the best you can and add missed steps during the training session.
d. do the job yourself first.

62. (641) When you must train subordinates on 'locally assigned tasks' other than those listed on the STS, where should you record this training?

a. On the STS/JPG.
b. On AF Form 623.
c. On AF Form 623a.
d. On AF Form 797.

63. (642) All of the following are responsibilities or functions of the Deputy Commander for Maintenance except for

a. ensuring that an efficient training program is established.
b. performing competent and timely maintenance on assigned equipment.
c. managing the financial operation of the the maintenance complex.
d. reviewing monthly maintenance training schedules.

64. (642) The main function of the Deputy Commander for Maintenance is to manage the maintenance complex by

a. planning the use of maintenance resources.
b. scheduling the use of maintenance resources.
c. controlling and directing the use of maintenance resources.
d. Doing all of the above.

65. (643) Within Maintenance Control, the unit that schedules the accomplishment of unscheduled maintenance requirements is

a. Job Control.
b. Plans and Scheduling.
c. Materiel Control.
d. Plans and Scheduling and Documentation.

66. (643) The staff unit of the Deputy Commander for Maintenance that is charged with managing the technical order improvement reporting program is

a. Quality Control.
b. Production Analysis.
c. Programs and Mobility.
d. Administration.

67. (645) At base level, the maintenance data collection (MDC) system provides the means of

a. planning and scheduling maintenance actions.
b. validating and initiating corrective action on maintenance problems.
c. managing assigned equipment resources.
d. Doing all of the above.

BEST COPY AVAILABLE

68. (645) In units where the maintenance management information and control system (MMICS) has been implemented, the supervisor uses the Monthly Man-hour Summary and the

    a. Maintenance Personnel Listing to keep track of the man-hour utilization in the work center.
    b. Master Roster to ensure that MDC forms turned in by the work center are correctly filled out.
    c. Master Roster to keep track of the man-hour utilization in the work center.
    d. Maintenance Training Roster to ensure that MDC forms turned in by the work center are correctly filled out.

69. (645) Productive-direct man-hours refers to the hours that have been expended by individuals

    a. actually working on the job.
    b. during duty hours no matter what they are doing.
    c. when they are at commander's call or meeting an appointment.
    d. Doing all of the above.

70. (646) The procedures for properly completing an AFTO Form 349, Maintenance Data Collection Record, can be found in

    a. the 00-20-2 series TOs.
    b. the 00-25-1 series TOs.
    c. AFM 66-1.
    d. AFM 300-4.

71. (646) What does job control number '001 0023' mean?

    a. The first work order on the 23rd day of the year.
    b. The third work order on the 23rd day of the month.
    c. The 23rd work order on the first day of the year.
    d. The 23rd day of the first month of the year.

72. (646) Of the six character code of an identification number used on AFTO Forms 349, the second character is derived from the prefix of what other code or number used on those forms?

    a. The equipment classification code.
    b. The component position number.
    c. The job control number.
    d. The command/activity identification number.

73. (647) When aircraft parts that are high-value or limited-availability items are sent to a maintenance shop for repair, they are normally referred to as

    a. NRTS items.
    b. DIFM items.
    c. HV-LA items.
    d. AWP items.

74. (647) While repairing an assembly in your shop, you find that you must order a new bearing from Supply before you can progress farther with the repairs. However, Supply informs you that the bearing must be back-ordered and will not be available for 5 days. What will be the status of the assembly during those 5 days?

    a. NRTS.
    b. AWM.
    c. AWP.
    d. DIFM.

75. (648) During an aircraft inspection, a maintenance inspector checks the work of a specialist who has just replaced a damaged bushing on a flap actuating mechanism. What phase of the inspection was the inspector involved in?

a. The fix phase.
b. The preinspection phase.
c. The postinspection phase.
d. The look phase.

76. (649) Which of the following is not one of the authorized maintenance inspection concepts?

a. Operational.
b. Isochronal.
c. Phased.
d. Periodic.

77. (649) Which maintenance inspection concept includes the thru-flight and basic postflight inspections but not the hourly postflight inspection?

a. Operational.
b. Isochronal.
c. Phased.
d. Periodic.

78. (650) A Category I materiel deficiency report should normally be submitted for which of the following reasons?

a. Quality deficiencies in material due to errors in workmanship during manufacture.
b. Quality deficiencies in materiel due to nonconformance to applicable specifications.
c. Materiel deficiencies that do not have a safety impact but which negatively effect operational efficiency.
d. Materiel deficiency that results in an inflight requirement to use prescribed emergency procedures.

79. (650) The materiel deficiency reports that must be electrically transmitted and that generate highest priority investigations are

a. Category I Reports.
b. Category II Reports.
c. Category III Reports.
d. all reports submitted on the Standard Form 368.

80. (651) A supervisor can utilize maintenance and inspection reports to help him identify

a. work bottlenecks.
b. possible training deficiencies.
c. methods of improving work-flow through the shop.
d. all of the above.

81. (651) To make a training chart most effective, it should not include

a. annual shot requirements.
b. hospital appointments.
c. leave schedules.
d. any of the above.

BEST COPY AVAILABLE

ATC/ECI SURVEY

The remaining questions (125-135) are not part of the Volume Review Exercise (VRE). These questions are a voluntary ATC/ECI survey. Using a number 2 pencil, indicate what you consider to be the appropriate response to each survey question on your answer sheet (ECI Form 35), beginning with answer number 125. Do not respond to questions that do not apply to you. Your cooperation in completing this survey is greatly appreciated by ATC and ECI. (AUSCN 100)

PRIVACY ACT STATEMENT

A. Authority: 5 U.S.C. 301, Departmental Regulations

B. Principal Purpose: To gather preliminary data evaluating the ATC/ECI Career Development Course (CDC) Program.

C. Routine Uses: Determine the requirement for comprehensive evaluations in support of CDC program improvement.

D. Whether Disclosure is Mandatory or Voluntary: Participation in this survey is entirely voluntary.

E. Effect on the Individual of not Providing Information: No adverse action will be taken against any individual who elects not to participate in any or all parts of this survey.

QUESTIONS:

125. If you have contacted ECI for any reason during your enrollment, how would you describe the service provided to you?

a. Excellent.
b. Satisfactory.
c. Unsatisfactory.
d. Did not contact ECI.

126. My ECI course materials were received within a reasonable period of time.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

127. The condition of the course materials I received from ECI was:

a. A complete set of well-packaged materials.
b. An incomplete set of well-packaged materials.
c. A complete set of poorly packaged materials.
d. An incomplete set of poorly packaged materials.

BEST COPY AVAILABLE

128. The reading level of the material in the course was too difficult for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

129. The technical material in the course was too difficult for me at my present level of training.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

130. The illustrations in the course helped clarify the information for me.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

131. Approximately, how much information in the course provides general information about your AFSC?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

132. Approximately how much information in this course was current?

a. Between 80 and 99%.
b. Between 60 and 79%.
c. Between 40 and 59%.
d. Between 20 and 39%.

133. The format of the text (objective followed by narrative and exercises) helped me study.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

134. The volume review exercise(s) helped me review information in the course.

a. Strongly agree.
b. Agree.
c. Disagree.
d. Strongly disagree.

135. Check the rating which most nearly describes the usefulness of the information in this CDC in your upgrade training program.

a. Excellent.
b. Satisfactory.
c. Marginal.
d. Unsatisfactory.

NOTE: If you know this CDC contains outdated information or does not provide the knowledge that the current specialty training standard requires you to have for upgrade training, contact your OJT advisor and fill out an AF Form 1284, Training Quality Report.

BEST COPY AVAILABLE

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 44 USC 3101. PRINCIPAL PURPOSE(S): To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with every ECI course package. It is utilized by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's need. Failure to provide all information would result in slower action or inability to provide assistance.

SECTION I: CORRECTED OR LATEST ENROLLMENT DATA: MAIL TO ECI, GUNTER AFS, ALA 36118

1. THIS REQUEST CONCERNS COURSE
2. TODAY'S DATE
3. ENROLLMENT DATE
4. PREVIOUS SERIAL NUMBER
5. SOCIAL SECURITY NUMBER ☐☐☐ – ☐☐ – ☐☐☐☐
6. GRADE/RANK
7. INITIALS ☐ ☐ LAST NAME
8. OTHER ECI COURSES NOW ENROLLED IN
9. ADDRESS: (OJT ENROLLEES - ADDRESS OF UNIT TRAINING OFFICE/ALL OTHERS - CURRENT MAILING ADDRESS)

ZIP CODE ☐☐☐☐☐

10. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE:
11. AUTOVON NUMBER
12. TEST CONTROL OFFICE ZIP CODE/SHRED

SECTION II: Old or INCORRECT ENROLLMENT DATA

1. NAME:
2. GRADE/RANK:
3. SSAN:
4. ADDRESS:
5. TEST OFFICE ZIP/SHRED:

SECTION III: REQUEST FOR MATERIALS, RECORDS, OR SERVICE

(Place an "X" through number in box to left of service requested)

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. The latest course workbooks have a Form 17 printed on the last page.

1 EXTEND COURSE COMPLETION DATE. (Justify in Remarks)
2 SEND VRE ANSWER SHEETS FOR VOL(s): 1 2 3 4 5 6 7 8 9 - ORIGINALS WERE: NOT RECEIVED, LOST, MISUSED
3 SEND COURSE MATERIALS (Specify in remarks) - ORIGINALS WERE: NOT RECEIVED, LOST, DAMAGED.
4 COURSE EXAM NOT YET RECEIVED. FINAL VRE SUBMITTED FOR GRADING ON (Date):
5 RESULTS FOR VRE VOL(s): 1 2 3 4 5 6 7 8 9 NOT YET RECEIVED. ANSWER SHEET(s) SUBMITTED ON (Date):
6 RESULTS FOR CE NOT YET RECEIVED. ANSWER SHEET SUBMITTED TO ECI ON (Date):
7 PREVIOUS INQUIRY (ECI FORM 17, LTR, MSG) SENT TO ECI ON:
8 GIVE INSTRUCTIONAL ASSISTANCE AS REQUESTED ON REVERSE:
9 OTHER (Explain fully in remarks)

REMARKS: (Continue on Reverse)

OJT STUDENTS must have their OJT Administrator certify this request.

ALL OTHER STUDENTS may certify their own requests.

I certify that the information on this form is accurate and that this request cannot be answered at this station. (Signature)

ECI FORM 17 JUN 77 PREVIOUS EDITIONS MAY BE USED

BEST COPY AVAILABLE

SECTION IV: REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of textual material should be forwarded directly to preparing agency. Name of agency can be found at the bottom of the inside cover of each text. All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:

MY QUESTION IS:

Course No. ____________

Volume No. ____________

VRE Form No. __________

VRE Item No. __________

Answer You Chose
(Letter) ___________

Has VRE Answer Sheet
been submitted for grading?

☐ YES ☐ NO

REFERENCE
(Textual support for the
answer I chose can be
found as shown below)

In Volume No: _________

On Page No: ___________

In______ (Left)_____(Right)
Column

Lines_____Through______

Remarks: